Dead Men's Eyes: Embodied GIS, Mixed Reality and Landscape Archaeology

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I, Stuart Eve, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

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Abstract

Archaeology has been at the forefront of attempts to use Geographic Information Systems (GIS) to address the challenges of exploring and recreating perception and social behaviour within a computer environment. However, these approaches have traditionally been based on the visual aspect of perception, and analysis has usually been confined to the computer laboratory. In contrast, phenomenological analyses of archaeological landscapes are normally carried out within the landscape itself, computer analysis away from the landscape in question is often seen as anathema to such approaches. This thesis attempts to bridge this gap by using a Mixed Reality (MR) approach. MR provides an opportunity to merge the real world with virtual elements of relevance to the past, including 3D models, soundscapes and immersive data. In this way, the results of sophisticated desk-based GIS analyses can be experienced directly within the field and combined with phenomenological analysis to create an *embodied* GIS. The thesis explores the potential of this methodology by applying it in the Bronze Age landscape of Leskernick Hill, Bodmin Moor, UK. Since Leskernick Hill has (famously) already been the subject of intensive phenomenological investigation, it is possible to compare the insights gained from 'traditional' landscape phenomenology with those obtained from the use of Mixed Reality, and effectively combine quantitative GIS analysis and phenomenological fieldwork into one embodied experience. This mixing of approaches leads to the production of a new innovative method which not only provides new interpretations of the settlement on Leskernick Hill but also suggests avenues for the future of archaeological landscape research more generally.

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Introduction

“‘And here,’ he said, stopping on a more or less level plot with a ring of large trees, ‘is Baxter’s Roman villa.’

‘Baxter?’ said Mr Fanshawe.

‘I forgot; you don’t know about him. He was the old chap I got those glasses from. I believe he made them. He was an old watchmaker down in the village, a great antiquary.’ ” (James 1992, p.293)

In his short story, ‘Dead Men’s Eyes' or 'A View from a Hill’, Montague Rhodes James tells the story of Mr. Fanshawe, who discovers a pair of field glasses made by an eccentric antiquarian. When he looks through them, he is shown a world that no longer exists:

“‘A good deal more to the left - it oughtn’t to be difficult to find. Do you see a rather sudden knob of a hill with a thick wood on top of it? It’s in a dead line with that single tree on the top of the big ridge.’

‘I do,’ said Fanshawe, ‘and I believe I could tell you without much difficulty what it’s called.’

‘Could you now?’ said the squire. ‘Say on.’

‘Why, Gallows Hill,’ was the answer.

‘How did you guess that?’

‘Well, if you don’t want it guessed, you shouldn’t put up a dummy gibbet and a man hanging on it.’

‘What’s that?’ said the squire abruptly. ‘There’s nothing on that hill but wood.’” (James 1992, p.295)

“There’s nothing on that hill but wood”. This is the challenge of being an archaeologist: most of the things that we are interested in are either buried, covered with trees or buildings, or have fallen down, never to be seen again. This is especially apparent when dealing with sites in the landscape. When I am walking through a ‘historic landscape’, I cannot see Fanshawe’s gory gibbet, or hear the rope creaking as the body blows in the wind. I can read a book, look on a map, excavate or find an old photograph or engraving of the area. But what if the mediaeval gibbet could seamlessly form part of the landscape as I walk around? Not as a special feature, just there, almost unnoticeable, part of my normal everyday world. Maybe then it would be possible to understand what it would have been like living with a gibbet on top of the hill behind my house, the stark judgement and reminder of the rotting corpse an integral part of the landscape in which I live. Perhaps then it would be possible to explore the past using a body-centred approach, to navigate through it with our bodies, and to undertake meaningful research into the archaeology of the landscape with an embodied perspective.

This thesis is about exploring that possibility. As Robin Skeates recently wrote "...despite the fundamental importance of the senses in human experience, archaeologists have generally neglected the abundant sensory dimensions of the material world they investigate" (2010, p.1). Although I would argue that this is not entirely true, and I explore the wide range of literature on this subject in Chapters One and Two, it is fair to say that the discipline of archaeology, and particularly landscape archaeology, has developed a dichotomy between those taking a computational approach to archaeological study and those taking a more experiential approach (see Eve 2012; Gillings 2012; Millican & Graves McEwan 2012 for recent discussions on this topic). The experiential approach, that is, an exploration of landscape using phenomenological or body-centred techniques (*e.g.* Tilley 1994), allows us to explore all of the sensory dimensions (at least of the modern world) using our bodies and various in-built senses. Attempts to use an experiential approach to landscape within a computer environment have primarily focused on using Geographic Information Systems (GIS) to recreate elements of human perception (*e.g.* Llobera 1996; Witcher 1999; Llobera 2001; Lake & Woodman 2003; Van Hove 2004; Frieman & Gillings 2007; Gillings 2009). While these computer-based studies have produced interesting results, they are not without their critiques (mainly due to claims of environmental determinism [see Wheatley 1993]) and, in particular, beyond some notable exceptions (Mlekuz 2004; Frieman & Gillings 2007; Gillings 2009), they have tended to focus mainly on the visual aspect of perception rather than encompassing all of the senses (see Thomas 2008 for a critique exploring the wider problem of ocularcentrism in archaeology; Rennell 2009, pp.37–49 for further discussion).

My thesis sets out to explore and bridge the 'middle ground' between the experiential and the computational approach to the landscape. I have developed new spatial analysis techniques (Chapter Five) and undertaken phenomenological fieldwork using the latest methodologies (Chapter Six) to investigate the Bronze Age landscape of Bodmin Moor, Cornwall, UK. These approaches separately provide new insights into the landscape and I successfully demonstrate that each has validity in providing new answers to old questions as well as posing new questions in and of themselves. Building on both of these methodological foundations and for the first time in archaeological analysis, I make a pioneering exploration of ways to bring these approaches together using newly emerging Mixed Reality techniques. Mixed Reality, and specifically Augmented Reality technology provides a platform to enable the results of computer analysis to be experienced within the landscape under study. As opposed to Virtual Reality (VR) or a traditional Geographic Information System (GIS) that recreates the entire world within a computer, Augmented Reality (AR) only creates parts of the world using digital methods and relies on 'Real' Reality to fill in the missing information. It enables an archaeologist to walk in the landscape under study, with the real landscape augmented by elements from their computational analysis. By using either a smartphone, tablet PC or a head-worn display, information can be overlaid on a screen, sounds can be played and even smells can be wafted to the nose, all of which happens while using the real landscape as a canvas. One still gets tired from walking up slopes, and feels the relief of sheltering from the wind in the lee of a hill, but this is accompanied by the sights, sounds and smells of the archaeological landscape merging with the modern landscape.

Within this thesis I introduce the concept of the *embodied* GIS, my idea and methodology for merging GIS analysis with phenomenological investigation, and a new way forward to help span the middle ground. I propose that this methodology is not simply for entertainment value or for enhancing the tourist experience of archaeological sites (although undoubtedly there is much to be said for both of these elements). Instead I present it as a way for archaeologists to explore their sites, to further test the hypotheses and results from their desk-based spatial analysis *within* the landscape and to provide further insights into the way in which their sites might have been used. It provides a means to ground-truth spatial analysis, and to refine computer models with information taken directly from an experiential engagement with the landscape in question. The embodied GIS is not a replacement for either technique; indeed, throughout this thesis I stress the vital importance of both the phenomenological and

GIS approaches; it is instead a platform which takes elements of both methods of investigation and combines them, without compromising the diligence or application of either.

The thesis is made up of three parts: Part One (Chapters One-Three) explores the theory behind both experiential and computational approaches to landscape study, and introduces Mixed Reality and the embodied GIS; Part Two (Chapters Four-Seven) documents my GIS and phenomenological investigations of the Bronze Age landscape of Leskernick Hill on Bodmin Moor in Cornwall and demonstrates the use and application of the embodied GIS; and Part Three (Chapter Eight) brings the discussion together and suggests ways in which the embodied GIS approach can be developed and used on other archaeological sites.

Within Chapter One I begin by exploring three main themes: philosophical theories of perception, the sociological aspects of experience and the application of technology to the representation of reality. I examine established theories of perception and mind including Cartesian Dualism, Monism, and Functionalism, before moving on to a discussion of phenomenology and body-centred approaches to archaeology. I examine the use of computer technology in representing human perception and how advances in artificial intelligence have re-sparked debate about the role that intentionality and qualia play in making up experience, and the difficulties this poses for practitioners attempting to recreate the human experience within a computer environment. I critically examine the use of phenomenology within archaeology, challenging some aspects of previous phenomenological methodology by showing that previous practitioners may have focused on certain aspects of the theory to the detriment of others. Finally, I present examples of the ways in which perception has previously been approached using Geographic Information Systems and suggest some ways in which these techniques might be adapted and developed.

Chapter Two is an exploration of the Mixed Reality environment. I present the Reality-Virtuality continuum and explore the various degrees of Reality-Virtuality from Real Reality to Virtual Reality. Alongside this discussion I describe and explore the concept of *presence*, a way of measuring the effectiveness of a virtual or augmented experience and the level to which a user feels involved, and introduce the Arc of Intentionality, a heuristic device explained by Turner (2007). The Arc of Intentionality is a way of assessing the level of presence in mediated experiences against four basic human states of intentionality (defined as internal psychological embodied experiences): the corporeal, the affective, the social and the cognitive. By coupling these states with the affordances of the outside world, Turner provides a way to document Breaks in Presence, the moments when the virtual experience does not tally with the real experience and therefore jars us, affecting the level of psychological flow.

With this theoretical basis in place, Chapter Three provides a number of examples of the practice of Mixed Reality, specifically in relation to archaeology. After presenting the necessary delivery mechanisms I examine the different types of Augmented Reality that are currently possible. I discuss a number of previous applications of AR and provide a case study that demonstrates the technical process behind creating an AR experience. Building on the technical and philosophical discussion, I outline my concept of the embodied GIS, and what steps I believe are necessary in order to use the emerging technology of AR to create a system for exploring GIS data within an archaeological landscape and for use within my case study (Part Two).

Leskernick Hill has been excavated and studied for many years and in Chapter Four I introduce the previous work on the site and surrounding landscape. Between 1994 and 1998 Leskernick Hill was subject to intensive survey and fieldwork by University College London. Alongside conventional archaeological excavation, the team also conducted ground-breaking phenomenological fieldwork which helped to develop the concept of body-centred archaeological survey and stands as an exemplar of the experiential exploration of an archaeological landscape. I discuss their conclusions from both the phenomenological work and more traditional techniques and use these as a basis for framing my own work within this case study. For the remainder of Part Two I undertake my own studies of the landscape of Leskernick Hill, with each chapter taking a different approach and methodology.

Chapter Five details a number of my computational analyses of the landscape using spatial statistics within a Geographic Information System (GIS). By concentrating on traditional viewshed analysis of the Leskernick Hill landscape I investigate the original conclusions of the UCL team and suggest some alternative possibilities. I then develop a number of new techniques to further investigate the landscape, with particular reference to the possible reasons for the settling of Leskernick Hill in the Bronze Age. By developing a series of 'spatial confidence' maps I demonstrate a new way to visualise and analyse the results of viewshed analysis using Monte Carlo simulation. I also introduce the concept of the 'visibility field', building on Gillings' work on Alderney (2009), an innovative method for examining which parts of the Leskernick landscape have the best visual connections to the ritual areas and those that may have been used for the extraction of tin by the inhabitants. The GIS analysis in this chapter shows the strength of the computational approach to landscape analysis and how it can be used to suggest and support new conclusions about archaeological sites.

Chapter Six, by contrast, introduces the experiential way of exploring and drawing conclusions from a landscape. Following methodologies outlined by Hamilton and Whitehouse (2006), I undertook a systematic phenomenological investigation of Leskernick Hill. My phenomenological site-catchment analysis enabled me to suggest the effect the form of the landscape itself may have had on the inhabitants of the Hill and show the range of different conditions and resources that would have been accessible within an hour's walk from the site. I also collected data relating to possible sound-dispersion and communication across the Hill, which itself suggests some interesting conclusions about the possibility of the placement of the settlement and the individual houses. Finally, I explore the nature of the possible use of the 'solution hollows', features carved into the surrounding granite tors, and suggest that, rather than being used as containers for libations (Tilley & Bennett 2001), they could have been more closely related to tin extraction.

In Chapter Seven I seek to combine the results from the computational analysis and the phenomenological analysis and use them to create a version of an embodied GIS. Using the methods outlined in Part One, I document the creation of two prototype embodied

GIS applications, one using location-based AR and one using marker-based AR. I present the results of a number of different tests undertaken with the applications, and use these to explore the Breaks in Presence caused by such an approach. Working from Bender *et al's* (2007) initial phenomenological experiments, I use the embodied GIS to recreate their experiments with house doorway orientations and provide an alternative to their results. Throughout this chapter I show that rather than being an alternative or a replacement to either the GIS or phenomenological approach, the embodied GIS can act as a glue between the different approaches, providing the best of both worlds.

Where Chapter Seven concentrates mainly on the visual aspects of AR, in Chapter Eight I concentrate on including the other senses within the embodied GIS. I demonstrate a number of ways to include sound, smell, touch and taste into AR and expand on ways in which these can all be combined to provide a deeper experience of the landscape. Using the data collected during my phenomenological fieldwork, I create soundscapes and smellscapes and use them in conjunction with the embodied GIS application, to explore my results *in situ*. In addition I show the ways in which the Breaks in Presence raised during my embodied GIS fieldwork can be approached and discuss the future direction of the embodied GIS hardware and software.

Finally in Chapter Nine I draw together the findings from all of the chapters and discuss how this innovative, multi-stranded approach could be used on other sites, and what implications my research may have for the future of archaeological landscape research. Throughout this thesis I aim to show that, rather than having to choose one set of methods over another, i.e. the digital versus the real, it is possible to combine the two without sacrificing the strengths of either. The embodied GIS brings with it advantages that are only possible by taking careful account of the reasons why each methodology works and how each one can create its own archaeological knowledge or highlight conclusions that may not have been obvious before. By using Augmented Reality and the embodied GIS as a tool for *researching* data rather than just *presenting* data, I also explore an avenue of Mixed Reality studies that has as yet remained sadly under-researched within archaeology and heritage management. The view from the hill is changing.

Part 1 - Theory

Chapter 1 - Perception and Reality

As explained in the introduction, in this thesis I will examine the liminal area where computer-based landscape analysis crosses with phenomenological analysis. I will also explore new techniques in Mixed Reality to assess if they offer an appropriate methodology to use to combine these two disparate approaches. My own approach, therefore, involves a number of different strands of investigation, which are interwoven throughout the chapter:

1. *Philosophical theories of perception.* I examine in detail previous explanations from the wide corpus of philosophical literature of the nature of perception and the human experience of the world. By utilising suitable philosophical theories as a 'tool for thinking' (Law 2003) it is possible to identify the practical applications of each theory. From this examination I will identify the most relevant theories and use these as a basis for the later configuration and clarification of a suitable Mixed Reality model.

2. *The sociological aspects of experience.* Experience can be said to be a social phenomenon (Hayes 1911). This is especially true when exploring archaeological landscapes or open-air heritage sites: “it is the social experience that frequently is best remembered” (Hooper-Greenhill 1999, p.21). However, the sociological aspects of a heritage site are not confined to modern-day experience, the experiences of past users and occupiers of the site are of great interest especially if some attempt is going to be made to communicate these sociological aspects to the modern archaeologist. Therefore I will examine the application of the relevant theories of perception and experience to past societies. This comprises an in-depth examination of the archaeological literature and aspects of current archaeological theory.

3. *The application of technology to the representation of reality.* There are currently many different ways that reality and perception have been re-created using various technological advances (for example, virtual reality simulators, video

games, simple photographic panoramas). I make an assessment of some of these techniques with particular reference to the cultural heritage applications of the technology. By relating the examination of these to the relevant literature gleaned from the other strands (philosophical and sociological), I am able to ascertain which techniques are most appropriate for my research.

Philosophical theories of perception

Any discussion involving the concepts of 'reality', 'experience' and 'perception' must inevitably begin with scrutiny of the philosophy behind these concepts. Throughout history humans have been fascinated with how we experience the world, what it means to be human and whether or not what we see, hear and feel are really how the world is. The philosophical literature is rife with 'isms' describing various schools of thought regarding past exploration of these topics, and one easily becomes enmired in the sheer volume of works on the human experience, as philosophical engagement with problems of perception and experience go back at least to the time of Plato (the whole of Western Philosophy consists of a series of footnotes to him, after all [Whitehead 1979, p.39]). With this in mind this chapter seeks to engage only with the theories that are most relevant to my study. Because I am interested in the interaction of the individual with their immediate environment and with heritage assets, an exploration of the theories of philosophy of mind and phenomenology that are directly concerned with the perception of the world from an individual's perspective can be considered the most appropriate.

Plato's Cave

Following Whitehead's assertion, it seems only proper to start with an examination of Plato, in particular his *Allegory of the Cave*. This is written as a fictitious conversation between Socrates and Plato's brother, Glaucon. It appears in Book VII of The Republic, and is used as an example by Plato to illustrate the rise of the philosopher from merely looking at a *shadow* of the world to understanding the *reality* of the world. A group of prisoners have been chained in a cave since birth in such a way that they are unable to move their heads. They can only look forwards at the wall in front of them, on which (due to a fire burning behind them) are cast shadows of a raised walkway. Along this walkway pass “men bearing all sorts of utensils ... and human statues, and other animals, in wood and stone, and furniture of every kind” (Wratislaw 1894, p.196). The prisoners can only see the shadows and hear the echoing noises and voices from the walkway, which they presume to be produced by the shadows themselves. There is “nothing true but the shadows of the utensils” (Wratislaw 1894, p.197). One of the prisoners is then released and taken to the 'real' world, where he is able to look at the walkway and life as we know it and realise that before, he only saw shadows.

Although Plato uses this thought experiment to explain attainment of the goal of higher reasoning, we can also use it to explore the nature of virtual worlds or alternate realities. Cruz-Neira *et al.* have previously used the Allegory of the Cave to this end – indeed the immersive Virtual Reality (VR) centre at University College London uses a system called 'The CAVE' (Cruz-Neira *et al.* 1992). The experience of VR is very much like the manacled prisoners, looking at a shadow of the real world. The difference for the modern VR user is, of course, that they are aware of the real world. They themselves have lived in the world outside the cave and, in common with the man who was set free, they can see the shadows for what they are. Does this knowledge of the 'real world' then mean that the shadows are no longer relevant? Or at least, that the shadows are now recognised merely as shadows and can never hold the same sway as the experience of the real world? If we follow Plato's simile to its conclusion, the released prisoner will look back on his former companions left in the Cave and “...will esteem himself happy by the change and pity them” (Wratislaw 1894, p.198). Plato's allegory has an important truth in terms of ethics, “...reality is to be preferred to appearances” (Keown 1998, p.85). Virtual Reality is clearly a representation (a shadow) of the real world, illuminated by the fire of the computer processor. Once armed with the knowledge of the origin of the shadows we are like the released man, recognising our time in the Cave as a mere representation of the outside world. The question is raised, then, as to whether or not we can suspend our belief long enough to become immersed in the shadow-world, or even whether it is possible to 'trick' our minds to accept the shadows as 'real'. Alternatively, the knowledge that we are seeing an alternate reality may in fact already prejudice us to inadequacies of the virtual world as we are “able to look directly at the sun itself, and gaze at it without using reflections in water or any other medium, but as it is in itself” (Lee 2003, p.258).

An extension of this argument is the question as to whether or not we even want to bother exposing ourselves to the shadow-world. What advantages does it bring us? Plato's prisoners in the Cave had no choice, but we (as did the released prisoner) can decide if we want to view the shadows or if we want to see the world for what it is. The question as to why we feel the need to immerse ourselves in video games, VR worlds and other alternate realities, even though we know them to be shadows, will be discussed in more detail later. However, the distinction between us and the prisoners is important here – the advantage of 'choice' is vital to the notion of a 'virtual' reality. The virtual world must bring with it something else that the real world cannot provide. Within the heritage sector this 'something else' is quite clear. The virtual world provides us with the opportunity to create shadows of past experiences, past lives and past environments.

Before I go onto discuss the advantages or disadvantages of using virtual reality for the reconstruction/representation of past environments however, it is important to further investigate the nature of human perception and how we experience the real world.

How do humans perceive the world?

This is a fundamental question forming the backbone of the philosophy of mind. A brief overview of the various schools of thought is necessary to place my arguments within the wider theoretical debate. I shall discuss several slightly different (although not always opposing) opinions on human perception, each of which is relevant to the way we experience the world and hence to the way in which we interact with and experience our surrounding environment.

Dualism

Two of the classic theories within philosophy of mind are the diametrically opposed ideas of Dualism and Monism. The basic conflict is concerned with the definition of what makes up mental and physical states. As Braddon-Mitchell and Jackson outline, “it is natural to distinguish what we might call the material, physical or bodily nature of a person from the mental, psychological or sentient nature of a person” (2006, p.3). However, the dualist and the monist differ in the nature of the ingredients needed to create the physical and mental states. A monist would argue that everything in the world is made up from some type of substance, and that mental states are just “an enormously complex construction and arrangement of the very same ingredients that make up our material natures” (Braddon-Mitchell & Jackson 2006, p.3). The dualist argues that mental states are too complex and too different in essence to be simply made up of building blocks of physical matter. It makes sense to argue that the feeling [mental state] of loss or love, for example, has no physical mass or weight; after all no-one yet has ascertained the atomic mass of love. It would seem to be logical because of this then to assume that the mental state is composed of something else. The question is, what is this and where does it exist? Descartes describes it as 'mental substance', the substance being something that requires nothing else to exist (see Wilkinson 2000, p.36). However, this is one of the main objections to dualism (especially Cartesian so-called 'two-substance interactionist' dualism), and one that even Descartes struggles to answer. Indeed, as Wilkinson states “... he offers no positive characterization of it whatsoever, and this is always a suspicious procedure in the construction of any theory ... this type of substance has just been invented to solve a logical problem” (Wilkinson 2000, p.39).

There are many objections to Descartes' form of dualism, the most relevant to my study being the problem of interaction. That is, how do the physical substance and the mental substance interact? When questioned on how the thought of moving one's arm actually makes the physical arm move, Descartes claims that the mind and body only interact in one place (his claim in the 17th century was that it interacted through the pineal gland). The classic rebuff to this asks why it is that the pineal gland is the only place where this interaction occurs? More importantly, as Gassendi (Descartes' contemporary) points out, if the mind does not exist in space, but the body does exist in space, how can the two interact at all, irrespective of the role of the pineal gland (Haldane & Ross 1931, vols.2, p.199–200)? Whilst Cartesian two-substance dualism has been challenged, the basic premise of the mind being different from the body still holds weight with a number of philosophers (Lycan 2009; Chalmers 2007) and the idea of the 'brain in the jar', i.e. that mind can exist outside of body becomes very relevant when dealing with the emergence of artificial intelligence. If we can artificially create or simulate thought (mental substance) within a computer (material substance) then we can explore the interaction between mental and material substance in a new way. The implications of this are pertinent to my study, and therefore it is important to have established the philosophical underpinnings of dualism. This subject is discussed in greater depth later in this chapter.

Monism

The alternative to dualism is monism and some version of it is held by most contemporary philosophers (Kim 2005). The most popular is some form of materialism or physicalism – the basic premise being that everything in the universe is made up of material substance and therefore the mind and also our thought processes, feelings, emotions *etc.* (Descartes' mental substance) are also made up of material substance. Wilkinson explains it thus:

> “To more and more philosophers, as to many other people, it has come to seem probable that sooner or later empirical science will provide us with a complete physicalist account of the nature of things, and it would be untidy if the mind resisted this approach, since it would then end up as an irreducible oddity in an otherwise physical universe” (2000, p.49).

One of the main pushes of the materialist philosophy is to challenge and remove the so-called 'nomological danglers' of dualism (Fiegl *et al.* 1958, p.428). This relates to the necessity of having unusual or special laws if mental sensations and consciousness exist outside of the physical realm (*e.g.* are irreducibly mental). Smart sums up the objections to nomological danglers thus:

> “I cannot believe that ultimate laws of nature could relate simple constituents to configurations consisting of perhaps billions of neurons (and goodness knows how many billion billions of ultimate particles) all put together for all the world as though their main purpose in life was to be a negative feedback mechanism of a complicated thought. Such ultimate laws would be like nothing so far known in science” (Smart 2002, p.61).

Whilst clearly a subjective view, Smart nonetheless highlights the unusual situation that would need to be enacted to mean that nomological danglers exist.

The most relevant form of monism to my study is functionalist materialism. Although a functionalist can be a dualist, the majority of functionalists are also materialists and hence monists. The main defining element of a functionalist philosophy is the approach to mental states. In Cartesian dualism the mental state is a substance, a thing, but from a functionalist viewpoint the substance of the mental state is not important – it is the function of the state that is key. “...what makes a mental state mental is that it has a particular causal role in bringing about behaviour in the context of a given set of sensory information and standing beliefs about the way the world is” (Wilkinson 2000, p.69). The functionalist is not concerned with what makes up the mental state – just what its function is. A worked example of an everyday situation makes this easier to follow - how do I cross a road? Firstly I see the road that I want to cross then, because of my childhood memory of the Green Cross Code government campaign, I follow the instructions 'Stop, Look, Listen'. I Stop on the edge of the pavement, when I Look, I scan the road for oncoming cars, and I Listen to detect if there are any unseen cars approaching. I am using experience and sensory input to determine my next move. Once I am happy that it is safe, I cross the road. There are a number of different processes taking place – by seeing the road I want to cross I am immediately reflecting mentally on how I can cross this road. This reflection can be considered a mental state and is brought about by a combination of sensory input, past experience and the process of making a judgement, and it results in an action (that of crossing the road). Shoemaker sums this up: “...mental states are defined, or individuated, in terms of their causal relations to 'inputs' (sensory stimuli and the like), outputs (behaviour), and one another” (Shoemaker 2000, pp.193–194).

As one of my main research aims is to investigate the use of experiential methods to investigate past human behaviour, functionalist materialism is relevant to my study, not least because it forms the basis of a number of different philosophies of mind that have developed throughout the 20th century. In addition, when looking at computer-based methods for investigating human behaviour, the theory of Artificial Intelligence (which I will discuss later) draws heavily on the materialist and functionalist literature. As with the philosophical underpinnings of dualism, it is important to discuss the major tenets and objections to materialism and functionalism in order to situate my study within the corpus of philosophical literature and debate. With this in mind one of the important arguments against a materialist perspective is that it does not provide a suitable explanation for the notion of privacy of feelings or subjectivity. By having to seek justification in the physical sciences it is difficult for the materialist to explain the unique feelings that we as humans all have. That is, if I feel pain it is a personal feeling to me and no-one else can have exactly the same feeling at exactly the same time. This means the feeling of pain is not publicly observable, therefore it is extremely difficult to prove objectively that my precise feeling of pain is the same as someone else's. Obviously the external manifestations of my pain (such as my wincing face and crying out) can be observed – but these are simply outputs, not the so-called 'raw feel' (Sturgeon 2000, pp.24–25) itself. Materialists such as Churchland (1981) have provided a response to this, challenging the use of so-called 'folk psychology':

> “'Folk psychology' denotes the prescientific, common-sense conceptual framework that all normally socialized humans deploy in order to comprehend, predict, explain, and manipulate the behaviour of humans and higher animals. This framework includes such concepts as *belief, desire, pain, pleasure, love, hate, joy, fear, suspicion, memory, recognition, anger, sympathy, intention,* and so forth. It embodies our baseline of understanding of the cognitive, affective, and purposive nature of persons. Considered as a whole, it constitutes our conception of what a person is.” (Guttenplan 1994, p.308).

By arguing that folk psychology is a set of empirical theories like any other that can eventually be disproved by advances in neuroscience, Churchland argues that the concept of privacy and subjectivity is not a valid objection to materialism.

Problems for Materialists

A major problem for materialists is the problem of *aboutness* (what philosophers usually refer to as 'intentionality'): this is the premise that all mental states are about something, i.e. I see a tree, or I hear a bird, or I want a cake. Mental states therefore always have an object – I never just 'want' I always want *something*. This is a problem for materialists (although not one that has not been extensively analysed, see Armstrong 1993; Graham 1998, pp.155–157; Shoemaker 2000) for a number of reasons, not least because aboutness needs to be accounted for within the physical world. Therefore, if the world is being described in purely materialist terms, then my desire for a cake needs to be represented by an account of (for example) brain neurons firing. However, whilst this may account for the mental state I am in it does not account for the brain neurons themselves. After all if they are either firing or not firing they cannot be said to be 'about' anything (Wilkinson 2000, pp.76–77). It could therefore follow that arrangements of matter are not 'about' anything and the 'aboutness' or 'intentionality' of mental states exist outside the materialist's philosophical vocabulary. Clearly there are counter-arguments to this, not least that it is the arrangement themselves that is important, for instance, is a complex DNA structure 'about' a phenotype (an organism)? Intentionality is an extremely important (and constantly debated) concept within studies of consciousness, and I will return to the subject when discussing phenomenology below.

A further (and not unrelated) objection to the functionalist viewpoint is the problem of qualia. Qualia are the qualitative aspects of mental states, such as the redness of a tomato or the itchiness of an itch. The inverted spectrum argument presented by Block and Fodor (1972) challenges the functionalist standpoint by presenting a thought experiment that involves a pair of twins. One twin (John) sees red the same way as a normally sighted person, the other twin (James) sees red as if it were green. Both twins react in the same way to the 'colour' i.e. they will both stop at a 'red' traffic light, but their visual experience of the traffic light is fundamentally different. The challenge to functionalism runs that even though the twins are exhibiting exactly the same behaviour (their sensory inputs and subsequent outputs are identical), their actual experience itself is different, and this difference has no way of being represented from a functionalist perspective. This holds even if the twins are merely reacting to the position of the red light in the sequence – certainly the top light being illuminated can mean stop, but the output is still the same and it is difficult for the functionalist to 'prove' that the twin was reacting to the position of the light, rather than its colour. How does this then translate if we are trying to recreate or investigate how past people would have reacted to or interacted with monuments in the landscape?

In terms of the use of qualia within the creation of virtual worlds or mixed realities this becomes an interesting dilemma. Is it something that can be just ignored? We know how to represent red within a computer, therefore even a person who sees red as green will still react to it as if it were red (see Nida-Rumelin 2002 for an explanation of the real physiological condition of spectrum-inversion). However, are we still presenting the same experience that we are trying to convey? By creating and observing the same reaction are we really creating the same *experience* (as the functionalist view would have us believe) or are we just creating the same *situation*? How much of our sense of perception is to do with the exact nature of our sensory inputs or just our reaction to the causal role that a mental state plays? How different is my experience from someone else's and can this ever be proved?

In order to consider these types of question we need to step away for a moment from what would be considered the traditional analytical realm of philosophy of mind and investigate a line of thinking that is usually omitted from philosophy of mind studies, because "...the goals, methods and doctrines are so completely separate from analytic philosophy of mind that the histories of the two traditions can be told in isolation" (Smith & Thomasson 2005, p.4). Reducing our view of the world to a series of properties that can be explained, documented and analysed invariably leads to what has been called *Entzauberung* – the 'loss of magic'. The word has been used most famously by Max Weber in his study on The Protestant Ethic and the Spirit of Capitalism (Weber 2001), but is used throughout 19th Century German literature to mean "...the loss of something fundamentally human, or else the link between human beings and the natural forces that supply their context and sustain them" (Cohen 1994, p.256). In other words, to avoid the loss of the fundamentally human in our study, we need to investigate the experiential view of the world revolving around the *person*, instead of the Platonic and materialist view where "the logical, representable properties of the world [become] more present and important than immediate sensuous reality" (Gosden 1994, pp.10–11).

Phenomenology

Phenomenology "is the study of conscious experience as lived, as experienced from the first-person point of view" (Smith & Thomasson 2005, p.1). One of the main reasons that phenomenology is rejected by traditional philosophy of mind is because it has been considered to be introspective and therefore not externally ratifiable. In order for modern materialist philosophers to argue that everything in the mind comes from material substance they need to be able to observe the physical causes (for example, specific brain neurons firing) of subjective feelings. Phenomenology, however (at least as argued by Edmund Husserl), is concerned with exploring the essences and relations of these experiences - not necessarily the empirical study of one's individual experiences *per se* (Smith & Thomasson 2005, p.6). In this way phenomenology and functionalism have some methodological aspects in common. Where functionalism seeks to explore and explain the function of mental states (and not what substance of which they are made) so Husserlian phenomenology seeks to study experiences and their *logical interrelations* – not the actual sensuous experience itself. By introducing the concept of 'bracketing', Husserl asks us to cut away certain presuppositions we may have (factual, social, cultural, *etc.*) to reveal the fundamental structure of assumptions that makes our experience of objects possible – he does not ask us to provide a reason as to why these are possible – but to provide a "description of the kinds of experiences we have without making reference to the epistemological status of such experience" (Sedgwick 2001, p.119). When I pick up my coffee mug by its handle and take a sip, how do I describe exactly what makes up this experience? If it is indeed possible to describe it, then it is possible to discuss much more objectively what the experience of drinking from a coffee cup actually is.

Husserl's phenomenology takes the concept of 'intentionality' (in the aforementioned 'aboutness' sense) to heart; he ascertains that everyday experiences all are 'about' something. I pick up *the coffee cup*, I see *a smile*, as with the examples discussed in the previous section – an experience always has an object. For Husserl, "consciousness is never without content" (Ferguson 2001, p.235), and this object is therefore always seen *from a perspective*. This is easy to understand from a human's point of view because we are used to being encased in a spatio-temporal body and observing from this 'perspective' (Kelly 2003, p.115); “the body is more than the point of spatial orientation, it is the centre of the phenomenal world in all its modalities” (Ferguson 2001, p.239). A knotty problem with this is that if objects are seen from a perspective then how does our experience of them transcend this (*e.g.* I know that when I look at a coffee mug that has the handle turned away from me that the handle is there, but just that I can't see it). The three leading phenomenologists (Husserl, Heidegger and Merleau-Ponty) are in disagreement about the nature of these indeterminate features of a perceived object and how we experience them. The exact details of this disagreement are not necessarily relevant here, but it is important to flag it as a point at which phenomenologists diverge. Merleau-Ponty, for example, rejected this idea of 'transcendentalism' and instead maintains that we cannot begin to address phenomena from an abstract point of view. Merleau-Ponty's view is also shared by Heidegger, diverging, however, in that for Merleau-Ponty, perception and the body *together* constitute the phenomenon that we are attempting to understand. That is, the coffee cup does not exist as a phenomenon in itself; the phenomenon that is of interest is our *perception* of the coffee cup from our *situated body*, effectively our embodied experience of it. Heidegger, in contrast, barely mentions perception and the importance of the embodied experience in his major work *Being and Time* (Carman & Hansen 2004, p.10).

These differing views have had a major influence on the use of phenomenology in archaeological practice. For example, in his 2004 book *The Materiality of Stone* Christopher Tilley concentrates heavily on the work of Merleau-Ponty, whereas Julian Thomas prefers to draw inspiration from Heidegger (Thomas 2002). As is clear, there is no one 'phenomenology' and archaeological phenomenologists have used a number of different works by different practitioners to aid and inform their fieldwork. It is important to note that not all archaeological phenomenology is the same, and archaeological practitioners have inevitably selected elements from the theoretical literature resulting in their own versions of phenomenology when undertaking fieldwork. However, before discussing previous archaeological uses of phenomenological theory in detail, and because my project focuses primarily on the experience of open-air heritage sites by an archaeologist investigating a landscape from a body-centred perspective, it is first necessary to expand a little more on the views of Merleau-Ponty in relation to embodied experience.

Merleau-Ponty has explored the concept of indeterminate features by suggesting that, although I cannot directly perceive them, they are within my sensuous experience. His approach is that consciousness [subjectivity] is inextricably “bound up with that of the body and that of the world, this is because my existence as subjectivity is merely one with my existence as a body and with the existence of the world” (Merleau-Ponty 2002, p.408). If we return to the coffee mug (a classic example used by Merleau-Ponty) we can begin to explore this further. Somehow, when I reach out for my coffee cup my hand already forms the correct shape to grasp it, knowing that there is a handle that I cannot see. This does not appear to be a conscious assessment of the situation, I do not have to stop, think and analyse the situation – I simply grasp the cup almost unconsciously – Merleau-Ponty calls this motor-intentionality (2002, p.110). Clearly I may get this wrong (or at least my body may get this wrong) as happened to me when someone presented me with coffee in a square mug. I grasped the mug cleanly by the 'hidden' handle, raised it to my lips and promptly spilled hot coffee down my front. My motor-intentional activity presumed that the cup was round and my body reacted to this (by pursing my lips in the appropriate way to drink from a round cup). Kelly (2003) provides a fuller discussion of motor-intentionality, including examples from recent perceptual-pathological studies that demonstrate the difference between a cognitive assessment of a situation and a motor-intentional response. It is not necessarily implicit that objects (or even situations) have hidden features that are always attributes of it to everyone who perceives the same cup. Hence the handle on the back of the coffee cup is not some special feature of every coffee cup, but it does show the relationship between the subject of perception and the object itself. I grasp the coffee cup in a certain way because my experience of coffee cups suggests to me (on an unconscious level) that a handle is likely to be there, when I am sitting at my desk with the cup placed in a certain position filled with coffee and that the coffee has been sitting there long enough that it is not too hot to pick up.

This type of experience of the hidden or indeterminate features of objects can also be applied to our perception of space. If our experience of indeterminate features can identify or predict the presence of a handle even if we cannot see it (or sense it) then the same can be argued for other indeterminate features of objects, such as relative distance, within an embodied experience. For example, if I am walking 100m to the next stile on a country walk, my experience of the distance of 100m is very different from that when I am competing in a 100m race and sprinting toward the finish line. Purely deterministically, 100m is exactly the same distance, but my perception of it is entirely different and it is essentially an indeterminate experience. It is important to remember that this comes from Husserl's first adoption of the concept of perspectivism. Merleau-Ponty developed this concept further and stressed the importance of the embodied experience, but the underlying theory is that experience of the world is situated within a perspective: “We are nothing but a view of the world” (Merleau-Ponty 2002, p.406).

This is particularly relevant when dealing with mental states that are 'about' objects or events that are yet to pass. For example, I may be thinking about the deliciousness of the cake that I am going to bake later. The cake itself doesn't yet exist (and may in fact never exist) – but nevertheless I can have thoughts or feelings about it.

Phenomenology and Archaeology

It is worth pausing here to consider how phenomenological theory can be practically applied and its implications for social theory; this is especially relevant when dealing with past societies and archaeology. These themes are explored in more detail later in the thesis and with particular reference to case-studies, but I provide a basic background here. Phenomenological studies within archaeology and sociology as a whole are still relatively rare, as Ferguson states, “sociologists and social theorists have found it easier to ignore than to criticize or assimilate phenomenology” (Ferguson 2001, p.242). Interestingly, archaeologists have been some of the main proponents in applying phenomenological techniques to the study of society (although see Ferguson 2001, pp.244–246 for other examples of purely sociological studies).

In the field of landscape phenomenology the triad of Bender, Hamilton and Tilley lead the way in the archaeological and anthropological literature (Tilley 1994; Bender 1995; Tilley *et al.* 2000; Hamilton *et al.* 2006, although see Helliwell 1996; Ingold 2011 for examples of non-landscape phenomenology). Their ground-breaking work on prehistoric landscapes and monumentality brought phenomenological theory to the forefront of (post-)modern archaeological thought and Tilley's 1994 volume, *A Phenomenology of Landscape,* inspired “a great burst of activity” (Thomas 2006, p.54) in the application of phenomenology to landscape archaeology. Initially, by concentrating on methods that were drawn from both phenomenology and ethnography and challenging the universality of contemporary Western conceptions of space and place, they explored different sensory landscapes and introduced the notion of self back into archaeological method. This was undertaken in a number of different ways, most involving an examination of modern-day embodied responses to sensory inputs, such as sight and, to a certain extent, sound.

One of the major criticisms of archaeological phenomenological practice is that it lacks a rigorous methodology, or at the least these methodologies are not explicitly stated, with the “implication that phenomenology lacks methodology and is thus disqualified from serious consideration as a distinct archaeological approach” (Hamilton *et al.* 2006, p.32; and see Brück 2005; Fleming 2006; Johnson 2006). These critiques are certainly valid for the early phenomenological work; for instance, *A Phenomenology of Landscape* contains very little explanation of the actual fieldwork methodology. However, later works such as those by Hamilton and Whitehouse on the Tavoliere Plain in Southern Italy (Hamilton *et al.* 2006) and the *Stone Worlds* publication of Bender, Hamilton and Tilley's work on Bodmin Moor in Cornwall (2007) are very specific about the methodology used and, in most cases, reproduce the recording sheets used during the fieldwork.

A more serious critique of the phenomenological approach to the study of past societies is that, by concentrating on the analysis of the embodied experience from the perspective of the phenomenologist, we are merely analysing the phenomenological landscape from the experience of the 'observer'. By extension this could mean that the phenomenologists are attempting to recreate the past in the present, a view that some authors have had difficulty with (Layton & Ucko 1999). Hamilton *et al.* put it thus: "...while the 'I' of the phenomenologist is resonant in descriptions of site experiences, the 'they' of past communities is rarely situated in the active tense" (Hamilton *et al.* 2006, p.35). Michael Shanks supports this view in his discussion of post-processual archaeology (of which he considers phenomenology a part), stating that it is hard for the archaeologist to "treat itself as a set of neutral algorithms for producing knowledge of the past" (Shanks 2008, p.137).

Whereas Husserl and Merleau-Ponty attempt to explore the nature of human perception and experience using phenomenological techniques, that is, by examining themselves and their experiences to get closer to a philosophy of the experiences themselves, archaeologists use phenomenological techniques to try to understand the perception and experience of past societies or past humans. As Rennell states, "...phenomenological philosophy crucially questions the fundamental nature of being and understanding the world, while archaeology aims to understand past societies" (2009, p.35). The distinction here is important, as Husserl's ideas of phenomenology are couched within a notion of temporality. The embodied experience is not just spatial but also temporal – for Husserl, temporality is part of every act of consciousness: "...every subjective process has its internal temporality" (Husserl in Ferguson 2001, p.240). Modern phenomenologists still struggle with investigating (and bracketing) their own perceptions in their own time but, as archaeologists using phenomenological techniques, we are also required to bracket and investigate the perceptions and experiences of people who may have lived thousands of years before us. Indeed, Julian Thomas suggests that bracketing is impossible and instead prefers to follow the work of Heidegger (Thomas 2006), who shuns bracketing and looks instead to the contextual relationships of objects in the world. This is clearly a paradox in the archaeological use of phenomenology and one that Hamilton *et al.* in the recent publication of their phenomenological fieldwork project on the Tavoliere Plain acknowledge, "...indisputably it is a delusion to think that we could ever wholly know how 'they' thought and interfaced" (2006, p.35). However, they argue, it is better to try and at the very least acknowledge the possibilities of different embodied experiences (such as children, women, old men, *etc.*) rather than just ignore them.

Tilley *et al.* in their phenomenological experiments with prehistoric monuments at Leskernick Hill on Bodmin Moor also approached this seeming paradox, but instead of using their own phenomenological analysis as a proxy for previous communities' perception they simply state “...we cannot recreate the meanings that the stones had to the Bronze Age inhabitants of the site. Our work is our creative response to their creativity or, better, the ruins of their creativity” (Tilley *et al.* 2000, p.43). As part of their phenomenological approach, they wrapped up a number of significant stones (their initial significance having been suggested through traditional archaeological fieldwork) using painted cling film. The painting served to make the stones become more “...concrete and individual. Their specific relationship to place, whether it be a house interior of the slope of a hill, becomes emphasized” (Tilley *et al.* 2000, p.52). Tilley *et al.* were attempting to explore the Bodmin landscape as it is now, but were using elements of the past landscape that still existed (that is, are still within their spatio-temporal perspective). This is a different approach from Hamilton and Whitehouse (2006) who explicitly explore past experience.

Archaeological landscape phenomenology is clearly a heavily debated subject, and the criticisms of both lack of published methodology and also the difficulty of using modern experience to extrapolate interpretations of past experience are compelling and deserve attention. However, Matthew Johnson suggests that whether or not a particular approach is considered 'phenomenological' is perhaps a matter of semantics, and perhaps this is a wider question we should ask of all modern landscape archaeology. He claims:

> We are all phenomenologists. Few archaeologists would now deny that it is necessary to consider issues of meaning and subjectivity to achieve a full understanding of archaeological landscapes, and further that they would accept the starting point of the phenomenological tradition, namely, that understanding human experience is necessary but is not a common sense undertaking. (Johnson 2012, p.279)

I explore both the Leskernick Hill and Tavoliere case studies in more detail in Part Two, specifically with reference to the possibilities of computer-based embodied GIS to approach phenomenological analysis. Before that is possible, and now that I have introduced the concepts of phenomenology, Merleau-Ponty's concept of the embodied experience, and how phenomenology has been applied within archaeology, it is necessary to return to the more traditional aspects of philosophy of mind and to investigate the possibilities of artificial intelligence and the attempts that have been made to represent (and indeed explain) the mind and perception within the framework of computing.

Artificial Intelligence (AI)

The debate surrounding the possibility of the recreation of the human brain within a computer is vast and outside the scope of this chapter (see Bechtel & Abrahamsen 1991; Copeland 1993; Searle 1986 amongst others for fuller debate of these issues). However, as one of my aims is to investigate the use of computer technologies to explore human perception, there are some key points that need to be considered and investigated. One of the main premises of artificial intelligence, at least within the realm of philosophy of mind, is that "... a machine can think simply as a result of instantiating the appropriate sort of computer program" (Wilkinson 2000, p.107). This is the concept that Searle refers to as 'Strong AI' (1990) essentially the belief that it is possible for a computer to 'think' in the same way as a human does, or, that all the mind consists of is an extremely complex computer program.

Many researchers (*e.g.* Churchland 1990; Haugeland 1997; Haugeland 1985; Putman & Putnam 1964) have suggested that the mind can indeed be replicated within a computer, some going further to suggest that the brain is simply a computer running complex software within our grey matter 'wetware'. Alan Turing suggested that the now famous Turing Test would be a suitable way of confirming that a machine was 'thinking' (Turing 1950). The Turing test consists of one computer and two people, of which one is an assessor. The computer and other person are set up in different rooms. The assessor asks any questions that they wish and the computer and person respond. If the assessor cannot tell the difference between the answers given by the computer and that given by the person, then the computer has fooled the assessor and can be considered to be an intelligent machine. This example would seem to be a good test of computer intelligence as it demonstrates that the computer is intelligent enough to deal with new situations (previously unknown questions - inputs) and respond in a suitably human way that is convincing to the assessor (outputs).

However, John Searle has challenged this view with a separate thought experiment, the Chinese Room Experiment (Searle 1990). Searle, originally a linguist, challenges the Turing Test (and indeed the whole concept of Strong AI) by attacking the basic philosophical tenets. He argues that the basic concept of a computer reproducing the syntactical responses needed to fool Turing's assessor is not the same as the computer understanding the semantics of the response. His Chinese Room Experiment runs thus: Imagine a (non-Chinese) man in a room with a large manual that tells him exactly how to match Chinese symbols with other Chinese symbols and how to respond to any questions posed in Chinese symbols. He has a big basket filled with Chinese symbols, but he cannot understand the symbols themselves; to him they look like meaningless squiggles. The rules in the manual might say take a certain sign from basket number one and match it with a different type of sign from basket number two. People outside the room who do speak and understand Chinese hand in bunches of symbols and the man inside responds with the correct symbols as outlined by the rule-book (Searle 1990). The point here is that the man inside the Chinese Room has no idea what the symbols actually *mean*, he is just following the manual (the program); the man is acting as a computer would. However, the responses are 'correct' and comprehensible by the questioners, and therefore he passes the Turing Test with flying colours. The questioners could be asking “What is your favourite pet?” and he could be replying “I used to have a lovely small dog called Charlie, but my overall favourite was my cat called Hammond” - but he would have no idea, in the same way that a computer has no idea about the actual meaning of its responses, just the syntax of the way the response should be formed. This distinction between syntax and semantics is key to Searle's argument – he is not suggesting that a computer cannot be created with a sophisticated enough program to speak Chinese with native Chinese speakers, he is saying that the computer doesn't understand the meaning of Chinese that it is 'speaking'. It follows that a computer can never become 'intelligent' because human mental states and even phenomenological experiences have intentionality or aboutness – *they have semantics* – if the computer cannot understand this then the computer is not a true mind.

There are a number of counter-arguments to the Chinese Room argument (in particular see Churchland & Churchland 1990; Dennet 1991, pp.435–440); however, it is not necessary for me to dwell on this any longer. What must be taken from this very brief overview, however, is that aboutness and semantics are an essential part of the way we experience the world and something that computers (as well as qualia) have a problem dealing with.

Summary

At this point it is worth summarising the preceding sections before we move on to look at how these philosophical ideas might be used in practice. During the brief discussion of Plato's *Allegory of the Cave* I introduced the idea that our perception of reality may simply be constructed of shadows on a wall. If we are not aware that we are looking at shadows then we have no choice but to accept what we perceive is the real way things are. It follows, therefore, that our perception of the world is intimately related to our current situation, our knowledge of our surroundings, our thoughts and beliefs as well as our direct sensory inputs.

In discussing dualism I explored the idea that the mind may exist separately from the body. Classic Cartesian two-substance dualism would suggest that mental states are so completely different from the function of the body that they are made of a different substance entirely. Materialists would disagree, stating that everything in the world is made from the same matter, therefore regardless of how complex the structure of our brain needs to be to create mind (and to enable us to 'think') it is just a result of our grey matter. This point of view necessarily means that everything that happens within the mind and brain should be externally observable – after all if we are simply made of complex moving parts we should be able to pull apart the machine and work out and scientifically test each part. It is, however, difficult to imagine how we can externally observe our own subjective thoughts and private feelings. As soon as we voice them or try to explain what we are feeling we lose the essence of the feeling itself and are merely talking 'about' the feeling and representing the feeling of the feeling with words. The philosophical idea of intentionality or aboutness goes someway to challenging the materialist point of view as the firing of brain neurons can never be 'about' anything; they are either on or off. The concept of qualia is also difficult to externally observe as my internal concept of red may be completely different from anyone else's, and yet externally we both react in the same way when we see a red light (the inverted-spectrum argument).

The brief discussion of AI highlights the difficulties of recreating intentionality and qualia within a computer environment. Currently it would appear that neuroscientific and artificial intelligence studies are not advanced enough to allow us to accurately recreate the human experience of the world within a computer environment. This may never be possible as “a total system of rules whose application to all possible eventualities is determined in advance makes no sense” (Dreyfuss 1992, p.257). As Searle has suggested with his Chinese Room argument, a computer can be programmed to produce the correct syntactical response to convince an assessor that it can speak Chinese, but it does not necessarily follow that the computer understands the semantics of the symbols. This is not a problem of hardware: even with parallel-processing super computers the philosophical problems remain. It is not the number of processes, it is the lack of content and meaning of the processes where the theory of mind as computer falls down. Interestingly, by suggesting that a computer is capable of being a mind merely through sophisticated programming (thereby not necessarily relying on specific hardware) proponents of AI are suggesting that the mind is something radically different from the body. The modern AI materialists have reached a paradox and are actually advocating a type of functionalist dualism (Searle 1990).

Phenomenologists address the mind-body argument from a different angle: rather than concerning themselves with the seemingly unresolvable argument about what experiences and mental states are made of, they study the nature of these experiences themselves. Often misunderstood by contemporary philosophers of mind, “the goal of phenomenology is not to record the 'feel' of one's own mental states, but rather to explicate the essential types and structures of conscious experience as lived ... the methods of phenomenology do not rely on an introspective 'peering inwards' at one's passing stream of consciousness" (Smith & Thomasson 2005, p.9). Where both Merleau-Ponty and Husserl prefer a bracketing of experience, Heidegger explicitly rejects it suggesting that the context of the experience is key. Husserl presents a more analytical approach to experience, attempting to break apart each experience into its constituent parts. Merleau-Ponty brings the embodied experience to the forefront, by introducing the concept of indeterminate features of perception. That is, the elements outside my immediate sensory perception but that I know exist (such as the hidden handle of a coffee cup). He argues that these indeterminate features can also apply to abstract concepts such as space and distance, and that dependent on my physical and mental make-up I will perceive space and distance in different ways. In his own words,

> "...the system of experience is not arrayed before me as if I were God, it is lived by me from a certain point of view; I am not a spectator, I am involved, and it is my involvement in a point of view which makes possible both the finiteness of my perception and its opening out upon the complete world as a horizon of every perception" (Merleau-Ponty 2002, pp.303–4).

Archaeological phenomenologists have concentrated on the embodied aspect of phenomenological theory, in particular the role of the embodied experience within a landscape. By either emphasising particular features (wrapping stones) or by detailed recording of personal experience within an archaeological landscape they have attempted to highlight the absolute necessity of 'being there' in space, place and time. Archaeological phenomenologists have taken the original philosophies and adapted their practices, with Tilley preferring the direct embodiment of Merleau-Ponty and Thomas the contextual exploration of Heidegger. Whether using their own perception as a proxy for past perceptions or simply exploring their own perceptions within the modern landscape as shaped by past experiences, being in the landscape and experiencing the moment is the essential requirement for exploring the experience of place. Merely sitting in a warm office and imagining what things might be like in the landscape is not good enough (except for exploring the experience of sitting in a warm office and thinking!).

Is it possible then, to reconcile some of these approaches to human perception of the world and the mind-body problem? Merleau-Ponty and the phenomenologists talk of the necessity of embodied experience to perception and experience of the world, yet the dualists and the proponents of AI suggest that the mind can live independently of the body – or that the bodily functions and senses can be somehow be programmed within a computing framework to render the body itself unnecessary. In order to explore this further I will take one aspect of phenomenological theory (that of Merleau-Ponty's concept of our indeterminate perspective of space) and examine how this has previously been presented within a computer environment, specifically using Geographic Information Systems.

Geographic Information Systems and Perception

A Geographic Information System (GIS) is a way of dealing with the creation, manipulation and simulation of space. In its strictest definition a collection of paper maps could be considered a GIS, but most GIS work is undertaken within a computer environment. However as Wheatley suggests, "GIS has always been 'beyond technology' because they are more important for what they can do for us than what they are" (2004). We are surrounded by GISs in the modern world, from the satellite navigation systems in cars, to Google Maps on our computers and the compasses in modern smartphones. We are never far away from a way of navigating space or a visualisation of space even if just in the form of a world atlas.

However, we need to remember that GIS, paper maps or even written directions on the back of an envelope are just a representation of the space in which we exist (see Thomas 1995 for discussion). From a phenomenological point of view, if I am reading directions or looking at a Google Earth 3D representation of space on a computer screen I am not actually having the same experience as if I were in the space itself. The phenomenologists see space as a medium rather than a container for action, something which is an active agent, constantly changing around us: "space does not and cannot exist apart from the events and activities within which it is implicated" (Tilley 1994, p.10). This, of course, is a heavily contested view and, bearing in mind that GISs have been mainly based around the theory of absolute space (in the Cartesian 3-dimensional sense), is a theory of space that is only recently starting to be considered within GIS studies (Couclelis 1999).

Archaeology has been a front-runner in attempting to use GIS to approach the challenge of recreating or presenting perception within a computer environment. However, these have traditionally been based on the visual aspect of perception (see Gaffney *et al.* 1996). In fact, in many cases, vision has been taken as a direct proxy for perception, perhaps because it is the easiest to investigate: “whereas prehistoric smells and sounds are long lost, the topographic skeleton which is a substantial determinant of visibility is often little altered” (Lake & Woodman 2003, p.692). This position is rightly being challenged; Frieman and Gillings (2007) argue that “...having successfully extracted vision from the sensorium we need to rise to the challenge of putting it back, and in so doing explore more fully the role played by the senses in shaping and structuring understandings (both past and contemporary)” (2007, p.6). Frieman and Gillings suggest that a 'sensory envelope' can be created within a GIS environment that does not necessarily simulate every sense, but merely gives structure to “our creative exploration of the sensory textures and affordances of a given locale” (Frieman & Gillings 2007, p.13). This is an intriguing approach, as they accept that it is extremely hard to accurately model sight, smell, feel, taste, *etc.* especially from an archaeological perspective, but the sensory envelope acts as a way of creating a 'sense-shed' without specifically stating what those senses or experiences are. In their own words, “the immediate challenge is not to quantify, measure or analyse, but merely to get to know the spaces and places within it” (Frieman & Gillings 2007, p.11). Following the work of Higuchi (1988) who suggests that within a given landscape, full sensory engagement (as opposed to visual alone) would take place within a zone encompassed by a radius equivalent to sixty times the height of the dominant tree species, Frieman and Gillings can calculate the size and shape of the sensory envelope and plot it directly within the GIS.

It would seem that that the sensory envelope is being used as a proxy for perception or “full sensory engagement” (Frieman & Gillings 2007, p.10). As an illustration of this sensory engagement, they give an example of the rushes from relict river valleys in the floodplain landscape of Ecsegfalva, Southeastern Hungary. The landscape is at first open and exposed, yet the subtle undulations in the floodplain hide the rush-lined river valleys from view. However, the sounds of the rushes blowing in the wind are clearly audible and “...would have provided a near constant aural backdrop to everyday life” (Frieman & Gillings 2007, p.10). Whilst this methodology takes account of more than just vision, it is difficult to see how much this changes the examination of perception in GIS. Instead, the people, settlements and sites are existing within a sensory bubble – but this bubble is not taking account of the other aspects that we are addressing within a phenomenological view of the world: the intra- and inter-site social ties, the unknown connection that people have with the outer world surrounding them, the indeterminate features of their own world. As discussed previously the embodied experience is vital to a phenomenological approach, but this is not just limited to the immediate senses, “... meanings of space always involve a subjective dimension and cannot be understood apart from the symbolically constructed lifeworlds of social actors” (Tilley 1994, p.11). A known road, for instance, may fall into my immediate sensory envelope – but a road is more than the view of tarmac leading into the distance, it is more than the smell of traffic fumes and the feeling of tarmac beneath my feet. A known road leads somewhere out of sight: it might be the road that leads home from work, or the road that you take when going to visit your elderly grandmother. I therefore know where the road goes and have a concept of what is at the end of it, or what the journey is usually like (the indeterminate features). Recreating and exploring the social and cultural connotations and pathways of the elements that fall within the sensory envelope is the real challenge. Merleau-Ponty's indeterminate features of space are not yet being accurately modelled. Perhaps this is simply not possible within the current software framework; Llobera suggests: “...current GIS/archaeology users are trying to overcome GIS limitations by improving their methods - how do we represent ‘cultural’ information? how much weight do we attach to it? how do we quantify it? - rather than reassessing their theoretical stance to represent and conceptualize space” (Llobera 1996, p.613). What is needed is a paradigm shift in the way that we use GIS to represent and explore human experience of the world. Both Llobera (1996) and Gillings (2009; 2012) are attempting this by exploring the concept of the affordances (Gibson 1986) being offered by the features in the landscape, rather than modelling the individual's sensory modalities. The focus is moving away from modelling the active participant (the viewer, the listener) towards modelling the features of the landscape under study that offer different affordances to the perceiver. This is an intriguing approach and I will expand on the use of affordances in the following chapter. As is clear from my previous discussions in this chapter, every human experience is different and subjective, and (as is also true within the history of archaeological phenomenological fieldwork) steps need to be taken to account for the virtually unlimited possibilities of human experience, including that of different genders and ages. This is also true of how we actually move through the landscape and how our micro-movements such as walking gait, head swivelling, *etc.* are different for every individual. I explore these issues further in Chapter Five, but perhaps Llobera and Gillings are not going far enough: to fully engage with an exploration of the landscape we may need to rethink the very platform in which we explore a digital representation of space and the objects within it.

Bringing Philosophy and GIS together

Throughout this chapter I have suggested that the body is essential to our perception of the world. If it were even possible to remove the body from our mental experience of the world, the 'brain in the jar', the experience would not be the same (or at the very best it would be a syntactically correct simulation of the experience, but without the semantic content, therefore a different type of experience). Due to temporality, intentionality, qualia, privacy of feelings, *etc.* it is completely impossible to experience the exact experience of someone else (never mind someone from a past society). What then are we left with? Well, we are left back where we started – we are a view of the world – but we are *our* view made up of *our* past experiences, thoughts, feelings, beliefs, *etc.* For a recreation or reconstruction or objective analysis of past experiences this is an untenable situation; however, if we are attempting to open a window onto the past, to give a glimpse of what (at the very least) sensory landscapes may have been then all is not lost. The important notion to realise is that rather than attempting to reconstruct or analyse the exact experience, we are merely offering the opportunity for the modern person to make, explore and analyse their own experience of the landscape in question. This is a vital part of being an archaeologist, using the evidence that remains to us today, to make interpretations about the past. Much as Tilley *et al.* did with the painted stones on Leskernick Hill, it is possible to highlight parts of the landscape that may or may not have had past importance and to allow modern archaeologists to make of them their own experiences. Tilley *et al.'s* work “does not aim at replication, but in situ transformation, reworking a sense of place into our present-day consciousness” (2000, p.60).

Current GIS systems were designed with a specific purpose in mind, that of modelling and documenting geographic features in the world, and whilst they can be used in many different geographic analyses, the current implementation of GIS was not designed to explore the complex issues of an embodied space. Husserl's theory of pulling apart an experience and documenting its constituent parts could provide the cataloguing system we need, and Merleau-Ponty's focus on the importance of embodiment could be the vehicle. I believe it is certainly possible to straddle the divide between pure phenomenology and GIS/computer-based spatial systems, but perhaps it is necessary to think outside the computer, or at least to put the computer back into the landscape.

Chapter 2 - The Mixed Reality Approach

My discussion of previous attempts at creating a sensory GIS has highlighted a number of issues. Although some attempts are currently being made they are limited to the confines of the existing GIS software, and are most usually undertaken within a computer lab, away from the landscape in question. Developing a sensory GIS is desirable, not least because it allows archaeologists to create new situations and conditions and to undertake replicable statistical experiments that would simply not be possible through phenomenological fieldwork alone. I believe it may be possible to create an embodied experience that addresses most of Husserl and Merleau-Ponty's phenomenological requirements with the added benefit brought by computer technology.

As I have shown in my discussions of phenomenology, the most important factor is the 'embodied' aspect: it is vital to have the experience *within the place itself*. Throughout this chapter I introduce and discuss Mixed Reality, as a way of combining computer technology and data with the real world. Mixed Reality techniques allow virtual objects to be experienced within a real space – blurring the boundaries between the real and virtual. In this chapter I present the various different types of Mixed Reality, which serves as a basis for a more in-depth discussion of the possible archaeological applications of Mixed Reality in Chapter Three.

Virtual Reality (VR) and the advent of Mixed Reality

At the beginning of the previous chapter I discussed Plato's Cave and some of its implications for the nature of experience and perception, particularly with reference to Virtual Reality (VR). The term Virtual Reality has now been accepted into modern everyday language, and the dictionary definition is “the computer-generated simulation of a three-dimensional image or environment that can be interacted with in a seemingly real or physical way by a person using special electronic equipment, such as a helmet with a screen inside or gloves fitted with sensors” (McKean 2005). In his work on the metaphysics of Virtual Reality, Heim suggests that there are countless different definitions or applications of VR, listing seven different aspects (see Heim 1993, chap.8) usually associated with any attempt to define or apply VR. The most relevant are:

- *Simulation* – Because modern computer graphics are so advanced, it is almost possible to fool an observer that a computer picture they are looking at is 'real'. It is for instance extremely rare for any official photograph of a celebrity in today's world not to have undergone some form of digital retouching to remove unsightly blemishes and so on.

- *Interaction* – Heim moots the 'Recycle Bin' on our computer desktops as an example of interaction. “The desktop is not a real desk, but we treat it as though it were ... The trash can is an icon for a deletion program, but we use it as a virtual trash can. And the files of bits and bytes we dump are not real (paper) files, but function virtually as files” (1993, p.111). Effectively what makes these computer-based representations virtually real is that we can *interact* with them, much more so than a rubbish bin shown in a movie, or a desk in a photograph of an office.

- *Immersion* – Usually involving some form of hardware such as a Head-Mounted Display (HMD) and/or gloves that provide feedback to the user, this is the notion of being immersed within the alternate or virtual reality. Essentially, this provides a full sensory experience to the user. This type of approach is especially relevant for applications such as flight simulators of modern aircraft, where even flying the plane is like a video-game. In fact as Heim says, “...when you are flying low in a F-16 Falcon at supersonic speeds over a mountainous terrain, the less you see of the real world, the more control you can have over your aircraft” (1993, p.113).

- *Full-Body Immersion* – This is slightly different to the previous definition in that rather than being encased in a suit, the body is unencumbered and instead the computer has a number of different sensors that detect where the user moves and changes the projections on a screen to compensate. You can move your hand as normal and your 'virtual' hand will be projected on the computer screen and can interact with virtual objects.

- *Telepresence* – By using robotics, medical surgeons are able to perform remote operations even though they are not actually present with the patient. They can remotely control the robot 'scalpels' and are shown an inside view of the patient's body from the cameras mounted on the laparoscopic tools. According to Heim this can lead to a 'psycho-technological' gap opening between the patient and the doctor. “Surgeons complain of losing hands-on contact as the patient evaporates into a phantom of bits and bytes” (1993, p.115).

Heim, writing in 1993, notes that - “... for us, technology and reality are beginning to merge” (1993, p.118). This is an important observation as modern technology is opening up avenues of exploration that perhaps have not been available in the past. The term Virtual Reality now really only covers one aspect of so-called virtuality. As technology has advanced over the last twenty years, we are able to merge computer-generated 'reality' with the real-world, the so-called Mixed Reality (MR) (Ohta & Tamura 1999). This has led to the creation of a scale of virtuality (the Reality-Virtuality [RV] continuum) first proposed by Milgram *et al.* (1995). As can be seen in Figure 1, the scale goes from the Real Environment (RE) through Augmented Reality (AR), Augmented Virtuality (AV) to a full Virtual Environment (VE) (Heim's concept of Virtual Reality as discussed above). Virtual Reality is no longer seen as the only alternative to real life; instead it is seen as the polar opposite to 'Real' Reality, with many dimensions in between.

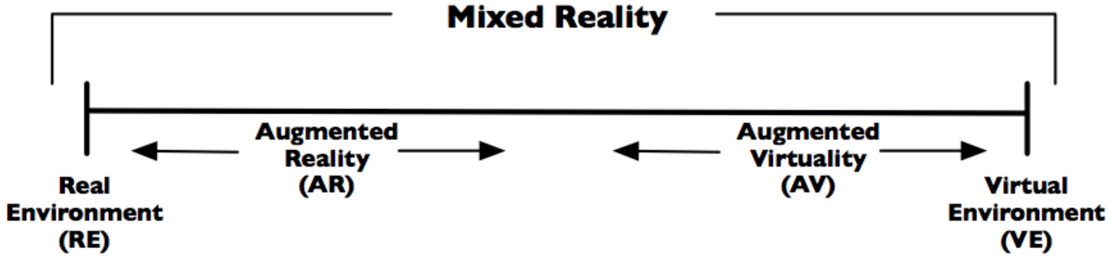


Figure 1 - The Reality-Virtuality (RV) Continuum (after Milgram et al. 1995)

This scale needs further unpacking, and Schnabel *et al.* (2007) have done so by defining further levels of virtuality within the overall scale.

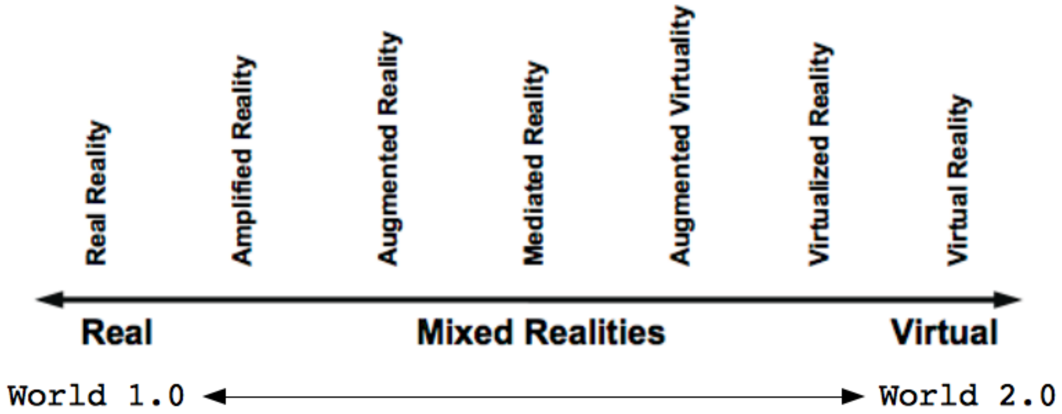


Figure 2 - Order of Reality Concepts from Reality (left) to Virtuality (right) (after Schnabel et al. 2007)

At a conference held in 2008 by the Centre for Advanced Spatial Analysis (CASA) at University College London, Andrew Turner described the creation of Virtual Worlds (as is possible with software such as Second Life) as 'World 2.0'; someone in the audience made the observation that they much preferred living in World 1.0. Although, to a certain extent, this was meant as a joke, it is actually a nice way of thinking about the difference between the Real World and a Virtual World. As can be seen in Figure 2, Schnabel *et al.* introduce a number of different concepts within the RV Continuum; by using the World 1.0-2.0 allusion we can assign fractal dimensions to the various different stages along the Schnabel scale. For instance, in this case Augmented Reality could be thought of as World 1.35. I will now examine some of the stages along the Schnabel scale to better explain these new concepts of virtuality.

Virtualised Reality

Virtualised Reality is a way of making real-world scenes virtual, by capturing a number of different video/photographic feeds of the scene from as many different angles as possible. These feeds are then converted into 3D space by use of stereo photogrammetry – effectively creating an exact 3D replica of the scene (or sequence of events) (Rander *et al.* 1997). This type of technology has been used for a number of different sporting events and to create big-budget films (such as *The Matrix*); it enables the real scene to be almost instantly virtualised, effectively allowing the action to be stopped and examined from any angle. Modern 'terasensors' (Carnegie Mellon University 2010) (so-called because they can capture up to 5.7 terabytes of data *a second*) not only capture data from cameras, they also capture sound using directional microphones, allowing a fully photo- and phono-realistic reconstruction of the scene.

This technology and concept is different from pure Virtual Reality. Whereas VR is traditionally used to create completely virtual worlds (that may or may not be reconstructions of real places), virtualised reality aims to completely virtualise the real world in action. Clearly this methodology has many implications for the way in which we record real-life events: one can imagine its use in the court-room (being able to minutely examine and re-examine the defendant's reactions to questions) or in archaeology where we could replay the excavation of a site from any different angle – and preserve the whole event by record. The telepresence aspects of this are interesting as well, a remote expert could examine the entire scene as if they were present and then advise the technicians on site. A significant amount of research has been undertaken on this application within the medical sphere (see Fuchs *et al.* 2007 for an example) with systems being created that allow a medical consultant to remotely view a trauma patient (from any angle) and communicate directly with the paramedic on site. However, the level of technology and equipment currently needed for this methodology is immense: the current terasensor at the Carnegie Mellon University consists of 1000 cameras and 200 microphones.

Augmented Virtuality (AV)

Augmented Virtuality takes one step closer towards World 1.0 but is still firmly rooted within a virtual world. In AV the primary 'world' is virtual and computer-generated, but real-world objects are brought into it. Examples of AV include overlaying the real-world coordinates of vehicles real-time into a computer-generated environment (for instance overlaying vehicle movements on a digital map). AV has been used to control systems for unmanned vehicles (Ahuja *et al.* 2007), video-conferencing (bringing video-feeds into a virtually-created meeting room) (Regenbrecht *et al.* 2003) and to track real-life movement of people onto their Second Life avatars (Fishkind 2009). Kevin Aires has developed a technology that allows you to use Augmented Reality 'MagicSymbols' (see Chapter Three) within a virtual world – which rather confusingly (and pointlessly?) means it is possible to dynamically overlay a virtual object (using a real-world technology designed to overlay virtual objects into a real-world) onto a virtual world (Aires 2009). This highlights the nature of the often blurred boundaries along the Schnabel scale.

One advantage of using Augmented Virtuality is that it is much lighter on real-time bandwidth than Augmented Reality (see below) as it is not tracking and analysing a live video feed. For military applications in particular this is important as remote vehicles do not always have reliable wireless radio links (Ahuja *et al.* 2007).

Mediated Reality

Mediated Reality sits in the centre of the Schnabel scale, implying that it is an equal mix of the Real and Virtual. However, Mediated Reality has been defined as a general framework for modification of human perception by altering sensory input (Starner *et al.* 1997). This does not always mean by use of computer-based technology and has even been taken to include prescription glasses and hearing aids (Mann 2002). Experiments with Meditated Reality were undertaken as far back as the 19th century, where George M. Stratton wore a pair of glasses that inverted his vision, so as to experience the world upside-down (Stratton 1896). It is important to note therefore, that whilst most of the stages along the Schnabel scale are achieved using computer assistance this does not necessarily always have to be the case, the feed of our sensorial perception can be altered by mechanical means as well.

Mediated Reality is often used to 'diminish' reality – that is to take away or replace a certain part of a person's perception. For instance, Mann replaces the view from the right eye with a wearable thermal imaging camera to allow a person to 'see' the heat signature of whatever he or she is looking at (Mann 2002). Whilst this removes the person's ability to see properly with both eyes, it also adds a new type of sensory perception. The term 'Diminished Reality' has also been used when using techniques to 'remove' certain parts of the landscape, for instance to give a view of how an urban landscape would look if a certain building was demolished (Lepetit & Berger 2001).

Mediated Reality can also be used to describe the centre ground where a number of different Mixed Reality techniques are being used. For instance, systems where real and virtual participants can interact are becoming more common in video-conferencing and collaborative environments (Regenbrecht *et al.* 2003; Schnabel *et al.* 2007; Hallmark 2010). This is the mediation between a real meeting-room where participants are meeting face-to-face but are also joined by remote participants and their avatars. The meeting itself can then be undertaken in a virtual meeting-room or a real meeting-room dependent on the preference of each individual. This also means the participants can manipulate a combination of both real-life and virtual objects within the participatory space.

Figure 3 - A meeting room with both real and virtual participants (using Virtual Conference Presence Solutions software - http://utsginc.com/Services/Communications/WebConferenceRoom.aspx)

Augmented Reality (AR)

On the Schnabel scale, Augmented Reality sits opposite to Augmented Virtuality (approximately World 1.35). In AV the majority of the world is 'virtual' and real-life objects are brought into that world. Augmented Reality works in a similar way except the world is real and the objects are virtual. Augmented Reality “...allows a user to work in a real world environment while visually receiving additional computer-generated or modelled information to support the task at hand” (Schnabel *et al.* 2007, p.4). This normally involves overlaying live video feed from either a web-camera, a Head-Mounted Display (HMD) or a mobile device, with virtual objects. There are a wide number of applications of this technology: interactive greeting cards (Hallmark 2010), advertising of various products (such as interactive brochures allowing you to 'drive' a car before buying it [Citroen 2010]), visualisation of computer-generated GIS data overlaid onto actual locations (Ghadirian & Bishop 2008), indoor and outdoor gaming (Bernardes *et al.* 2008), even heads-up displays (HUDs) in modern aircraft are a form of augmented reality – overlaying information from the aircraft's systems and projecting them onto the pilot's display. AR is currently quite rarely used in any fields for *interpretation* of data, and is mainly used for *presentation* of data, and this is also true of the archaeological examples. I expand on some of the archaeological applications of AR in Chapter Three. However, these almost exclusively concern tourism or cultural heritage management (such as the recreations of historic buildings or archaeological tours).

The applications of the technology are almost endless and it is rapidly becoming a tech buzz-word. An examination of the Google Trend data comparing the search frequency of the terms 'Virtual Reality' and 'Augmented Reality' (Figure 4) shows that Augmented Reality overtook Virtual Reality as a search term and a news item within 2009.

Figure 4 - Google Trends showing the change in search patterns since 2004 for Virtual Reality (red) and Augmented Reality (blue) - http://www.google.com/trends?q=augmented+reality %2C+Virtual+Reality&ctab=0&geo=all&date=all&sort=0 [accessed 22nd May 2013]

Although Google Trends data does not necessarily mean that AR is any more important than VR, and the pattern may in part be explained by the fact that people are naturally searching for a new technology, it does, however, suggest that there is a technological move away from the purely virtual back into a real world with virtual elements: AR is definitely "… entering the collective consciousness" (Schonfeld 2010). The development and application of AR technology has been moving at terrific rate in the last five years – Schnabel *et al.*, discussing the early prototypes of AR in 2007, compare its development to the early years of VR "in that many systems have been demonstrated but few have matured beyond laboratory-based prototypes" (Schnabel *et al.* 2007, p.5). As the Google Trend data shows, interest in AR has now exploded, resulting in a full AR-enhanced edition of Esquire magazine complete with Robert Downey Jr. explaining the technology (Esquire 2010) and even AR-enhanced cereal packets (King 2009). One of the major reasons for this is that modern smartphones and laptops come equipped with the appropriate hardware to make Augmented Reality possible. The technology of Augmented Reality is discussed in more detail in Chapters Three and Seven; essentially all that is needed to view an AR product is a web camera, or for mobile Augmented Reality applications such as Layar (Layar 2013) or Google Glass (Google Inc. 2013), a GPS-enabled smartphone with camera, digital compass and accelerometer.

Augmented Reality is perhaps also making an impact because it is much closer to the real world than VR: it allows new objects to be created and inserted into the real world, but "still holds the real elements and analog conditions as an indispensable part of its nature" (Ma & Choi 2007, p.36).

Amplified Reality

"To amplify reality is to enhance the perceivable properties of a physical object, by means of using embedded computational resources" (Falk *et al.* 1999, p.276). Although the boundary between Augmented and Amplified Reality is slight, there is an important distinction: where Augmented Reality adds new *virtual* objects into the real world, Amplified Reality alters the properties of *existing* objects. The concept is quite subtle, and Falk *et al.* use the example of painting a wall in the real world to describe the difference between AR and Amplified Reality. If you want a new colour on your wall in your bedroom, you could wear a HMD (or indeed coloured eyeglasses) and view the virtual colour (AR). However, repainting the walls themselves (changing the properties of the wall) means anyone entering the room can perceive the new colour, thereby amplifying rather than augmenting reality (Falk *et al.* 1999). This example, however, does not use any computer mediation, and amplified reality is always via some form of computational or electronic resource. An example of using computers and electronics to amplify reality can easily be seen in audio technology "...microphones, amplifiers and loudspeakers are used to amplify the expression (*e.g.* loudness), or functionality (*e.g.* the use of feedback and distortion), of musical instruments" (Redström *et al.* 2000, p.105). "An amplified object is self-contained in regard to its properties" (Falk *et al.* 1999, p.276), that is, the properties are embedded in the object, whereas using AR they are superimposed on the object.

Back to World 1.0

The degrees of virtuality and reality as defined in recent literature are varied, and each stage has a different implication for my project. Archaeology has taken advantage of some of the elements along the Schnabel scale – specifically Virtual Reality and Augmented Reality – and I present examples of some archaeological applications in the following chapter. However, so far I have only described the basic concepts within the RV Continuum. I will now discuss aspects of Mixed Reality (MR) with reference to the previous chapter's discussion of embodiment and perception.

As Mixed Reality becomes more pervasive in any number of different spheres, much interest has been garnered in the role of embodiment and perception within MR. This started with the investigation of embodiment within Virtual Reality (Biocca 1997; Hillis 1999). This is particularly with reference to the role of virtual objects being brought into the real world (AR). Within the computing sphere and the majority of writing about MR the concept of 'presence' is much discussed (Heeter 1992; Witmer & Singer 1998; Zahorik & Jenison 1998; Wagner *et al.* 2009; Pujol & Champion 2011). This has stemmed from early discussions of telepresence and immersion by the VR community, where one of the overriding aims of creating an 'authentic' immersive experience was the re-creation of a 'feeling of being there' (Heeter 1992). This feeling of *presence* - 'being in the world' is particularly pertinent in light of my earlier discussions regarding personal perception and phenomenology. Presence is subjective and psychological as well as objective and physical (Slater & Steed 2000). It has also been described as the way in which a person sees how they are related to the wider environment, i.e. a person is him- or herself, as opposed to a table in the corner (Wagner *et al.* 2009, p.251). A closer examination of some aspects of presence is necessary to continue the discussion of how people relate to artificial or virtual objects or worlds, particularly when dealing with real-world applications.

Ditton and Lombard (1997) argue that presence can be divided into social and perceptual realism: every part of the experience needs to feel ‘correct’ or ‘real’ - including the social interactions - in order for a feeling of presence to be maintained. Although difficult to define precisely, most agree that ‘presence’ means the perceptual illusion of non-mediation, and the ‘user’ acting in a mediated environment as if the mediation is not there. That is, they behave the same way in a virtual or augmented environment as they do in the real world (see Sylaiou *et al.* 2010).

Affordance and the Arc of Intentionality

I consider that the most appropriate definition of presence is related to Husserl's theories on intentionality (or aboutness, mentioned in the previous chapter) as envisioned by Phil Turner. Using the concept of Gibsonian affordances (Gibson 1986), Turner explores how presence can be maintained within a ‘synthetic’ environment or set of objects. It is important to note that Turner's use of affordances is indirectly based on a 'relational' model: the affordances are not exclusively present when being directly experienced by a human and they do not exist independently of a human but instead exist as *relationships* between the object and the human (see Chemero 2003 for further discussion). The human cannot perceive the world without the objects and the objects cannot be perceived without the human; it is the interplay between the human's states of intentionality and the object's inherent properties that create the relational affordance. In an archaeological example explored in greater depth in Chapter Five, Gillings advocates the use of the relational model of affordances as a way to explore the megaliths of Alderney (2009) and to begin creating a heuristic frame to further investigate past perception of places using GIS (2012).

Turner's work encompasses both phenomenological study of the embodied self and the individual’s relationship with the surrounding environment. He presents an ‘intentional arc’ which brings together the embodied being and the environment and is a useful heuristic device for examining the effectiveness and level of presence that a mixed reality experience conveys.

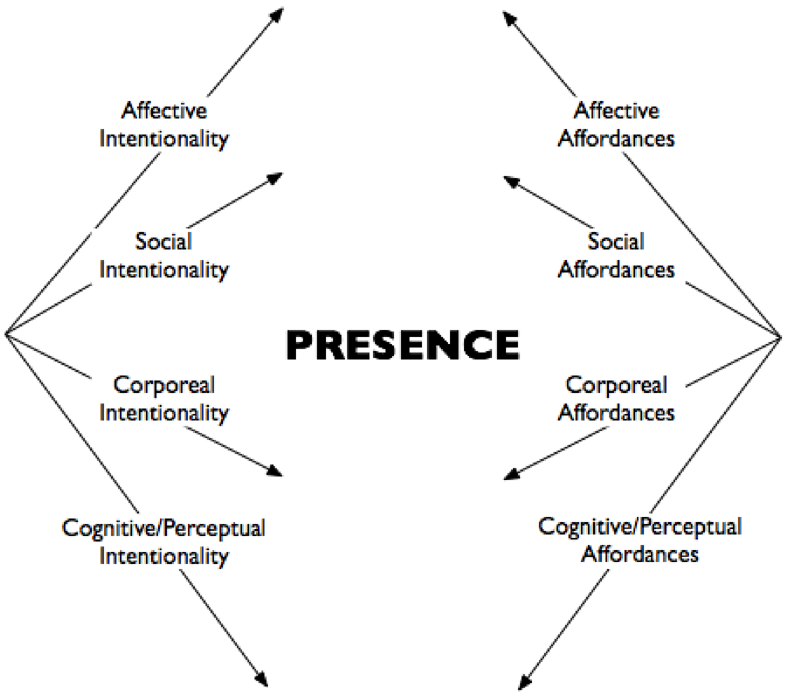


Figure 5 - The Intentional Arc (Turner 2007, p.130)

Turner builds on the concepts of social and perceptual realism put forward by Ditton and Lombard, outlining four types of intentionality (defined as *internal*, *psychological*, *embodied experiences*), all of which are coupled with external events, things and people (described as *affordances*). Together these form a so-called 'arc of intentionality', comprising:

Corporeal Intentionality: This is essentially synonymous with Merleau Ponty's idea of embodiment, i.e. whilst our corporeal body moves – it is our *perception* of this movement that creates the world around us. In this way the world *affords* us opportunities, the coffee cup *affords* grasping.

Social Intentionality: Turner describes this as our ability, as social animals, to predict, relate to and attribute mental states to others and to ourselves. It has been argued that it is this ability that enables us to create and maintain complex social relationships (see Humphrey 1976). This can be thought of as our ability to "anticipate the behaviour and intentions of others" (Turner 2007, p.129). Other people's behaviour gives us *cultural affordances* that we interpret and react to.

Affective Intentionality: This is the feeling of our own body and its relationship to our mental state. This is a combination of the bodily responses to external and internal stimuli (affordances) and the mental states produced as a consequence. Confronted by an axe-wielding maniac, the mind and body command you to run for your life. The associated physical consequences, such as a pounding heart, breathlessness, and kick of adrenaline, all contribute to the mental state of being afraid. As Turner explains, “the association of characteristic bodily states with hypothetical experiences and responses establishes a connection between the emotion and the world (that was or might have been)” (Turner 2007, p.129).

Cognitive/Perceptual Intentionality: This is the interplay between our actions and our thoughts. Our perceptual senses are directed at the external world – the information they collect is about things and events in the world (Turner 2007, p.130). However, this perceptual sense is also closely connected to the way in which we move and the actions that we perform. We would not be able to walk successfully (use our motor functions) across a city without adjusting to the constant perceptual inputs. Turner, therefore suggests that this interplay is of note and is important in assessing presence.

How then does this all fit together in relation to presence (and embodiment) within mixed reality? It is clear that in order for a sense of presence to be experienced anywhere along the Schnabel scale, the Arc of Intentionality must be maintained. The level of this maintenance will govern how well one receives the virtual information. For instance, to use an archaeological example, if a bronze knife is augmented into a real-world scene, it must afford us the same characteristics as it would if it were a real object. This means one would expect to see the light glinting from the blade (the surface affording reflection), would expect to be able to pick it up (the handle affording grasping), and would expect it to be able to cut another object (the blade affording slicing). In addition if one was able to pick it up and use it violently on another person, one would expect to have the same feeling of horror or guilt as if it were real (the use of the knife in that social context affording those emotions).

Therefore if these affordances tally with your state of intentionality, then the Arc of

Intentionality is maintained. However, if something doesn't quite fit (for instance, the light from the bronze knife reflects oddly) then the arc is slightly broken and there is a jarring of the experience. Turner refers to this as as *Break in Presence* (BiP) (Turner 2007, p.132). This is not just confined to virtual experiences – for instance, if I pull the trigger of what I believe to be a real gun and find it is in fact a cigarette lighter – I am jarred in the same way. I then learn that this is a special type of gun with a different set of affordances and know better next time. Therefore, it is possible to learn how to use new objects within a virtual environment: although the augmented knife may not look anything like a knife (creating a BiP from its visual affordances), it may cut virtual objects as a real knife does – thereby satisfying other aspects of the expected (or learned) affordances of a knife.

By using the Arc of Intentionality to measure presence during an experience we are better placed to judge where and why these BiPs occur and to approach what this means (and whether or not it is of relevance). For example, if the aim of a project is to create a fully immersive environment where the virtual world is indistinguishable in every way from the real world (full VR) then *any* Breaks in Presence would likely impact heavily on the project. However, if the aim is to create an augmented virtual meeting room (with real and virtual representations of the participants) – then the arc could be stretched a little and only certain affordances (such as those affording cultural/social interactions) would be necessary to get exactly right – other aspects (such as the recreation of the virtual meeting room decor) could be seen as secondary. These 'secondary' aspects could then be isolated, discussed and acknowledged. There are complementary ways of identifying and investigating the level of presence of an experience, such as monitoring physiological effects (i.e. increased heart-rate or sweating) and partaking in structured questionnaires (although see Slater 2011 for a critique of this) and a full investigation of presence would benefit from a combination of approaches. The Arc of Intentionality fits the aims of true Husserlian phenomenological investigation to explore the essence and inter-relationships of experience (see Chapter One). Using the clear methodology and language of the Arc of Intentionality, we are able to dissect an experience and examine its constituent parts.

My discussion of the concept of the Arc of Intentionality in relation to theories of phenomenology and affordances, alongside my discussion of the RV Continuum and the Schnabel scale, means we are now in a much better position to approach assessing and creating certain mixed reality experiences and applications within archaeology. Although archaeological examples of the use of Augmented and Mixed Reality techniques are limited, the next chapter introduces some of these and discusses their relevance to my study and the creation of an embodied GIS.

Chapter 3 - Mixed Reality Technology and Archaeology

Following my discussions of the theoretical underpinnings of perception, phenomenology, mixed reality, and presence, I will now examine the practical methods for creating a mixed reality experience and how such approaches have been applied archaeologically.

Archaeologists have worked extensively with full Virtual Reality applications (see Renfrew 1997; Gillings 1999; Barceló *et al.* 2000; Ryan 2001; Zhukovsky 2001; Gillings 2005; Bruno *et al.* 2010 for examples). It would seem that the main purpose of archaeological VR has been to "make archaeological information ... visually real" (Renfrew 1997, p.7). The Rome Reborn project, a comprehensive digital 3D model of ancient Rome, states its aims are "to spatialize and present information and theories about how the city looked at this moment in time, which was more or less the height of its development as the capital of the Roman Empire" (Frischer 2013). It is important to distinguish between a 3D reconstruction (such as the Rome Reborn model) and a true VR experience in which the user has some interaction with the model, usually visually via the use of a headset, or haptically via virtual reality gloves. Not all Virtual Reality applications are simple visualisations of data (see Goodrick & Earl 2004) and some, such as the Second Life recreation of Çatalhöyük, a Neolithic site in Turkey (Morgan 2009), encourage an active exploration and interpretation of archaeological data. However, as Gillings has warned, a large number of archaeological VR applications are in danger of being seen merely as "deficient surrogates" (1999, p.252). As outlined in the previous chapter, if a VR experience that is attempting to be fully immersive suffers any Breaks in Presence, these have a heavy impact and therefore many such VR projects get stuck in a cycle of refinement, attempting to get closer and closer to an exact replica of reality, unconsciously attempting to eliminate BiPs and thereby creating a gallery to be gazed at, rather than an active model to be explored.

As previously stated, I believe that it is vital to be embodied in the actual space under study: rather than trying to recreate the world in its entirety, we can use the real world to build on. For the purposes of this chapter, then, I will mainly consider the Augmented

Reality part of the MR Continuum, as this allows the inclusion of the virtual objects into the real world.

An AR experience is usually created via some kind of mediation with a computer or computer-based technology. As previously discussed, AR can also be mechanical (such as the use of ordinary spectacles); however, as I am here looking at how to combine the power of computer-based analysis with the embodied experience most of my archaeological information is digital and so the focus is on computer mediation techniques. Currently computer-based AR is mainly focused on augmenting visual perception, frequently by overlaying virtual objects into a video feed delivered to the user either by a Head-Mounted Display (HMD) or a computer screen connected to a camera (either a tablet or desktop computer). In Chapters Seven and Eight I provide worked examples of how to specifically deploy an AR experience on an archaeological site.

Here I examine the method behind creating the experience and introduce some essential terminology. I will first discuss the practicalities of deploying an AR experience, and as an illustration I provide a worked-through example of a desk-based archaeological application using a model of a Roman fort. Once the appropriate terminology and methodology is in place I will then examine previous archaeological applications of AR, and finally, I present my manifesto for an *embodied* GIS: combining GIS and phenomenological approaches to the landscape using AR.

Deploying Augmented Reality

Augmented Reality experiences can be deployed in a number of different ways, using a number of different delivery devices. The three main methods that I will discuss are Location-Based AR, Marker-Based AR and Projection Mapping. Each of these methods have advantages and disadvantages, which I will explore in further detail, before commenting on their possible impact on the successful deployment of an archaeological AR experience.

The AR experiences themselves are usually built within a software environment, and may be written as a stand-alone application (in the native machine code, programming language or via a scripting language) or the AR software libraries may be incorporated as part of other applications, such as gaming engine software. A game engine has been defined as existing "to abstract the (sometime platform-dependent) details of doing common game-related tasks, like rendering, physics, and input, so that developers can focus on the details that make their games unique" (Ward 2013).

Before discussing the methods of creating the AR experience, I will briefly examine the various delivery mechanisms available.

Delivery Mechanisms

An AR experience can be deployed in different ways and each method can use a variety of different mechanisms to mediate the experience. The delivery device is an important factor when assessing the Breaks in Presence of an experience, as it has a large impact of the feeling of presence and psychological flow (see Brooks 1999).

The two most popular ways to deliver a visual AR experience are via the use of a Head-Mounted Display (HMD), also known as a Head-Worn Display (HWD) (Feiner *et al.* 1997; Höllerer *et al.* 1999) or via a handheld tablet computer or smartphone. The HWD involves the user attaching a device that mediates what they see to their head. This can be a completely closed system, where the information fed to the eyes is via one or more video screens bringing information from cameras on the outside of the device (a Video See-Through [VST] HWD), or else via a device that overlays information directly onto a see-through screen, meaning the user is seeing the real world through their own eyes (an Optical See-Through (OST) HWD) (Rolland & Fuchs 2000).

Figure 6 - The Oculus Rift - a video see-through HWD

Figure 7 - The Vuzix Wrap 1200 - an optical see-through HWD

By wearing a device on the head the AR experience is delivered directly into the user's field of vision. This has a number of advantages, their hands are left free, and, because the AR content is visible wherever they look it becomes a more immersive experience (Klinker *et al.* 1999). HWDs can be quite heavy and cumbersome, particularly if they also contain other sensors to record the position and attitude of the head. Particularly in the case of VST HWDs, the need for external cameras raises issues of calibration, to accurately reflect the feeling of seeing the outside world, and resolution, as the screens need to be good enough to fool the eyes into seeing the real world with a 'normal' sense of visual acuity. VST HWDs struggle with presenting a truly parallax-free view to the user, mainly because the user's eyes are offset from the position of the video cameras (Zhou *et al.* 2008, pp.197–198). While OST HWDs present a seamless, uninhibited view of the real world, they suffer from problems with occluding objects in the real world with the virtual content (Zhou *et al.* 2008, p.197). A study by Sharples *et al.* (2008) shows that the use of HWDs is more likely to lead to 'cybersickness', a form of motion sickness that occurs from continued exposure to a VR environment, although similar studies of HWDs for AR use have not been undertaken. HWDs can also be expensive, particularly the solutions that use see-through displays. A pair of Vuzix STAR 1200XLD OST glasses currently retails at around $4999 (Vuzix 2013), a substantial outlay for an archaeological project. However, as the technology develops the prices will drop, and adequate solutions are likely to become more affordable in the next few years.

The alternative to using HWDs is to deliver the AR content via a laptop, tablet or a smartphone. By using the built-in sensors (GPS, compass, accelerometer, camera, *etc.*) this can be a low-cost approach to AR. Typically in this case, the video feed from the on-board camera is augmented with virtual information (a non Head-Worn Video See-Through AR). The device is used as a window onto the virtual content and this delivery results in more of a 'Magic Mirror' experience (Figure 8), such as that at Cluny Abbey, where a moveable screen can be used to view a virtual reconstruction of the Abbey *in situ* (Landrieu *et al.* 2011, pp.35–36). The user holds the tablet up to view the AR content, producing a less immersive experience, but it has the advantage of being a low-cost approach, and, as many people now have smartphones, it enables the experience to be accessed by a much larger number of people than if more specialist equipment (such as HWDs) is needed.

Figure 8 - The 'Magic Mirror' effect at Cluny Abbey, France. (Soler 2011)

Projection-Mapping is a third delivery mechanism for Augmented Reality. This does not involve either HWDs or a video screen, instead, projectors project the augmented information directly into the physical space. This method is currently most often used to project images, videos or animations onto building facades and the results can be stunning (Figure 9). The software uses a virtual 3D model to calculate the projection parameters, meaning it is possible to make the projections appear to bend around the building or surface itself.

Figure 9 - Animation projected onto the facade of the Shiekh Zayed Grand Mosque, UAE. Image taken from http://vimeo.com/33764021 – accessed 13th June 2013.

Projection-mapping is a useful way of augmenting reality for multiple users, and the advent of 'pico-projectors' which are small enough to put in a pocket has meant that projection AR is being experimented with on a more personal level. The 'Sixth Sense' system developed by Pranav Mistry (Mistry & Maes 2009) uses a camera that recognises specific gestures and physical objects alongside a pico-projector to project information onto nearby surfaces. This enables the user to use the physical surfaces as interfaces, for instance by projecting a numeric keypad onto the palm of a hand and using it to dial a number.

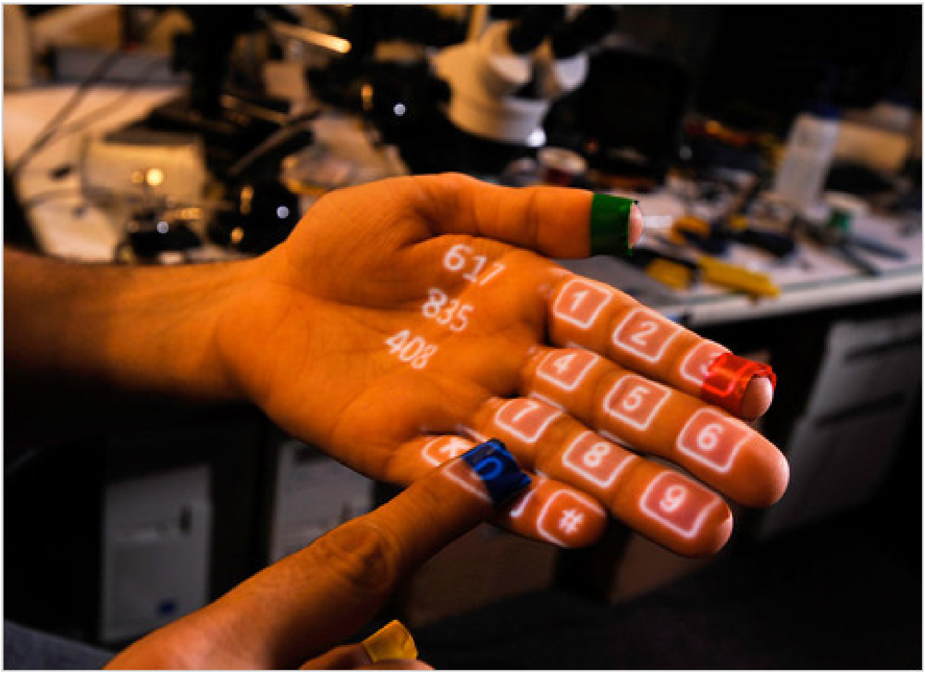


Figure 10 - Using your palm to dial a number with Sixth Sense (Bajaj 2013)

Projection-mapping has a number of drawbacks. First, the projectors themselves are usually quite expensive and difficult to move, especially if projecting onto a building. Second, it is affected by the ambient lighting level, so does not work particularly well in direct sunlight. Finally, the surface being projected on usually has to be blank or flat; when using rough or highly coloured surfaces the projection is not as effective.

AR practitioners are also delivering AR experiences by augmenting sounds via headphones and haptic responses via gloves. The Japanese company Lovotics has even invented a set of prosthetic lips that remote users can use to exchange kisses across the internet (Lovotics 2013). There are also examples of augmenting smells - although museums such as the Jorvik Centre have long been piping smells into rooms, to create the atmosphere of open sewers running through a Viking town (Aggleton & Waskett 1999). I will explore these devices and other applications in further detail in Chapter Eight, when I look at augmenting all of the senses.

Once the delivery mechanism has been chosen, it must be linked to a system able to interpret the real world and augment the experience accurately upon it. This is normally achieved using various types of sensor, including video cameras, digital compasses, GPS chips and accelerometers in a similar way to that used by pure VR experiences (Rolland *et al.* 2000). The difference between the tracking needed for VR and AR experiences is that AR also needs to be overlaid or mingled with the real world – meaning that the mechanisms needed are more complex.

Location-Based Augmented Reality

One of the overriding concerns when deploying an AR experience is that when the content is supplied to the user it must be correctly registered against the real world. For the digital content to be placed accurately in relation to the user, the AR delivery device needs either to have knowledge of the user's current location or to be able to interpret what the user is seeing in real-time, or a combination of the two.

The two main ways that this can happen is by using a location-based methodology or a computer vision-based methodology (Kipper & Rampolla 2012, pp.36–41). Location-Based AR, as the name suggests, utilises the user's location to correctly place the AR content. This is usually achieved by the combination of a GPS chip, compass and accelerometers (Torpus & Tobler 2011), but the location can also be gleaned using other triangulation techniques, such as Wi-Fi signal degradation (Benford 2005; Magerkurth *et al.* 2005; Reitmayr & Schmalstieg 2003). The GPS chip gives an X,Y,Z location, which means the user can be placed within a 3D space and any new movements recorded (translation); the digital compass gives a direction in which the user is looking (rotation); and the accelerometers provide the pitch, yaw and roll information. By combining the in-built sensors, Six Degrees of Freedom (6DoF) movement can be modelled – meaning that the relative position of the virtual content on the video screen can be calculated. The accuracy of the registration depends on a number of factors including the quality of the device: this is especially true of GPS coordinates as the Assisted GPS units within smartphones or tablet devices can often be quite inaccurate, leading to a misplacement of the virtual content, sometimes by up to 8.3m (Zandbergen 2009). While this possible shift is not too noticeable when viewing distant virtual objects, it has a major impact on objects viewed at a close proximity. There is also a problem with the latency of the virtual content, which means that the virtual content can sometimes 'lag' behind the movement of the real world, especially if the device is moved very quickly (Jacobs *et al.* 1997). Essentially, good registration demands accuracy and speed from nearly every component of the system and near-perfect system calibration (Holloway 1997). As hardware and software technology advances, the speed and accuracy of the sensors and algorithms are improving, meaning that the impact of these problems are reducing. However, they are still not yet entirely solved.

Location-based AR is used for a large number of AR applications in many different fields including advertising, navigation, task support, art, sightseeing, gaming and education.

Figure 11 - the lifeClipper system (taken from http://www.ubergizmo.com/2012/03/lifeclipper-virtual-reality-helmet/)

The lifeClipper project (Torpus & Tobler 2011) uses a VST HWD and a back-mounted differential GPS device to provide an immersive cultural tour of the medieval quarter of Basel (Figure 11), smartphone applications such as Layar (Layar 2013) provide an AR view to display local points of interest, and the Plane Finder App (Planefinder 2013) shows the real-time positions of planes currently in flight when the user points their smartphone towards the sky (Figure 12).

Figure 12 - the PlaneFinder App

Marker-Based AR

As opposed to location-based AR, marker-based AR relies almost solely on computer vision algorithms to accurately place the virtual content within the delivery device. A physical marker is placed within the real world and when this marker is viewed by the AR application, the marker is replaced with digital content. The basic process for marker-based AR is outlined in Kipper & Rampolla (2012, pp.32–36) and is as follows:

1. The live feed from a camera is supplied to the computer processor.
2. The video stream is digitised and the marker is identified by the use of border-detection and the creation of binary encoded patterns.
3. The position of the marker is sent to the AR software, which positions and orients the virtual content in relation to the physical marker.
4. The virtual content is overlaid onto the video stream in the correct position and orientation.
5. The virtual content is rendered into the frame and the video stream, with the AR content viewable on the display device, either a monitor, smartphone or heads-up display.
6. This process is repeated for every video frame.

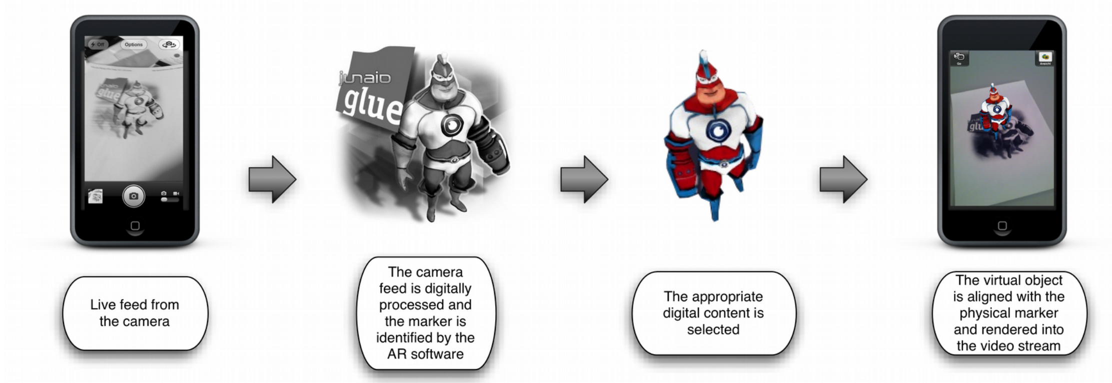


Figure 13 - Registering digital content using a marker-based approach

Marker-based AR generally provides a more robust AR experience than location-based AR as it solely relies on computer vision algorithms (and a camera) rather than a collection of different sensors. However, it does suffer from a number of drawbacks (see Kipper & Rampolla 2012, p. 36); these include:

- *Occlusion of the marker.* If the marker itself is occluded or is only partially in view of the camera the algorithms can struggle to identify it.
- *Unfocused camera.* If the camera becomes unfocused and the details on the marker are not clear it can lead to non-recognition of the marker.
- *Motion Blur.* Some cameras, especially on mobile devices, create motion blur if they are moved too quickly, this can interfere with marker recognition.
- *Uneven lighting.* Many marker recognition algorithms convert the video frame into a binary image, before looking for the marker. If the lighting is uneven or there are strong shadows, this can obscure the marker in the binary stage – meaning it is harder to recognise.
- *Contrast and Variance.* The marker image itself needs to have a certain level of contrast, this is why black and white images work so well – as it is easy for the algorithm to identify certain parts of it. In addition, the image cannot be entirely symmetrical as this can lead to problems with the marker being interpreted upside-down.

Marker-based approaches were one of the earliest forms of AR and the open-source software project ARToolKit (Kato *et al.* 2000) brought marker-based AR to the forefront. ARToolKit's use of simple black and white fiducial markers enabled many of the early AR researchers (*e.g.* Fiala 2005; Liarokapis *et al.* 2004; Piekarski & Thomas 2002) to experiment with vision-based code-libraries, and the ARToolKit is still in use today (Yamaguchi & Yoshikawa 2013). However, the concept behind the algorithms has moved on from the need for a simple black and white fiducial marker and now virtually any type of image can be used as an AR marker. As I demonstrate later in this chapter, software libraries such as Qualcomm's Vuforia AR library (Qualcomm 2012) provide a Software Development Kit (SDK) that enables developers to use their image recognition algorithms within existing applications to provide AR experiences.

It is possible to combine location-based and marker-based approaches, by utilising markers or images as calibration points for the location-based applications. A Latitude Longitude Altitude (LLA) marker encodes GPS coordinates within the marker that can then be used by an application to reset the current GPS coordinates to match those encoded in the marker (Madden 2011, p.274). This is particularly useful for location-based AR within areas of limited GPS coverage, or for indoor navigation.

A Worked Example

I present a landscape-wide approach to using Augmented Reality in Chapters Seven and Eight. However, to explore the basic techniques I created a prototype AR application based around the physical model of a 'Build Your Own Roman Fort' (Ashman & Millard 1988). I decided to use the model as it provided a ready-built 'real' environment to experiment with in a controlled manner, before moving the techniques to a wider landscape scale. Whilst the use of a Roman fort as a prototype in a thesis which contains a substantial Bronze Age case study may seem an odd choice, the relatively simple geometry of the fort allowed experimentation with occlusion, as well as the opportunity to experiment with virtual content interacting at different levels of the model.

My aim was to use AR techniques to populate the paper model with digital content, to enable the user to explore the fort and consider how certain buildings would have functioned. Following my previous discussion, I decided to develop within a gaming-engine environment using the industry-standard engine Unity3D (Unity Technologies 2012). I am using Unity because it allows rapid prototyping of concepts, along with excellent support for a number of different platforms, including iOS, the operating system used by Apple's tablet computer, the iPad. Unity provides the basic building blocks for creating an AR experience, it has an in-built physics engine, rendering engine and a basic user interface meaning that the amount of code that needs to be written from scratch is reduced. Unity also has in-built support for Qualcomm's Vuforia AR library, enabling the creation of highly customised marker-based AR experiences.

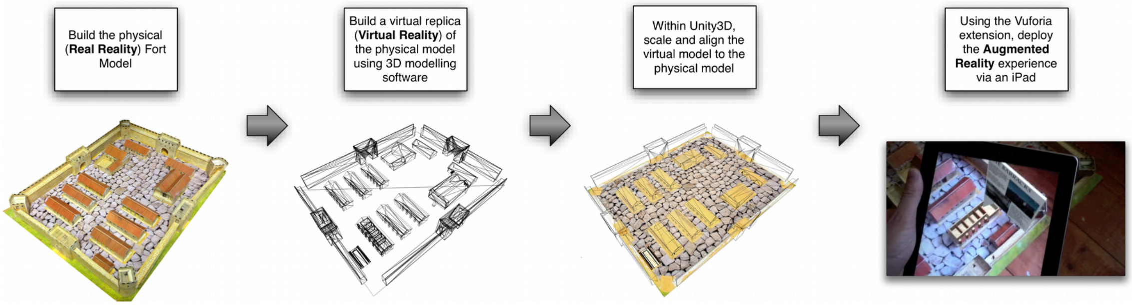


Figure 14 - The basic workflow for creating the FortAR application

As can be seen from Figure 14, the basic workflow for creating the Fort AR application involves a number of different steps. Before assembling the paper model, I printed a custom base image for the fort and attached the model buildings to it. The custom image acts as the 'marker' to be recognised by the AR image recognition library. It was necessary to create a new base, as the base that is supplied with the fort itself does not have sufficient contrast or variability to be accurately identified by the Vuforia software. Once the physical model was assembled, the next step was to recreate the physical model (Real Reality) in the virtual environment (Virtual Reality). I built a scale model of the paper fort within 3D modelling software (Figure 15).

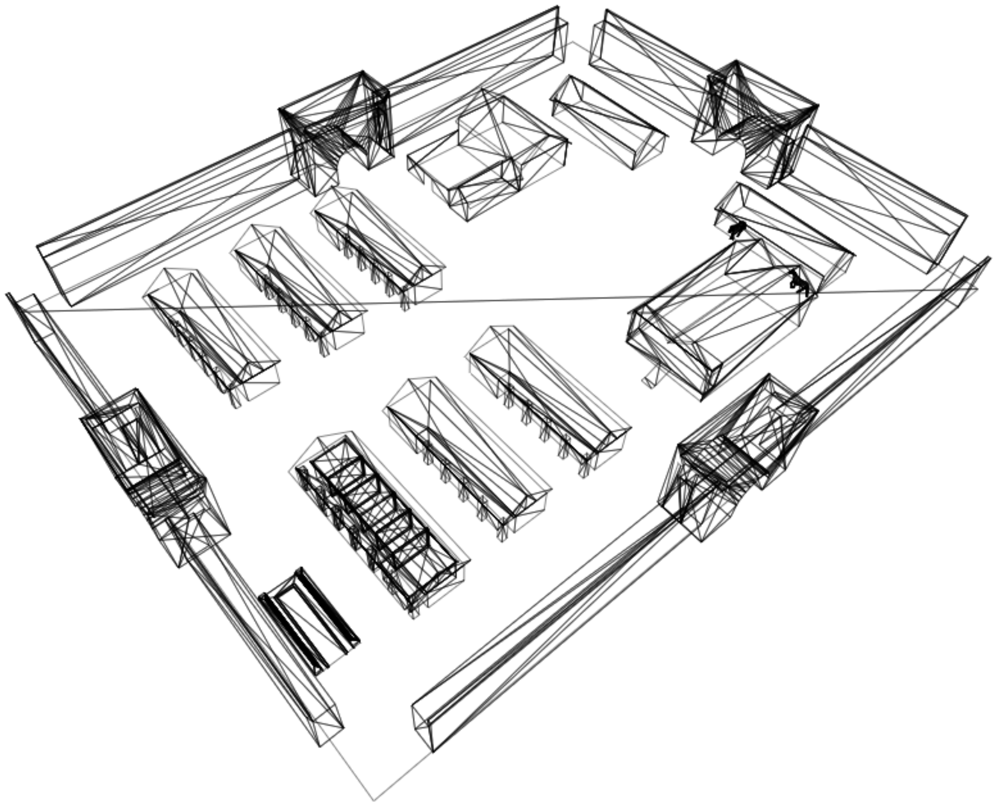


Figure 15 - The 3D model of the fort

One of the obstacles of AR (marker-based or location-based) is the problem of *occlusion (Wloka & Anderson 1995; Shah et al. 2012)*, that is, making it seem as if the real world is occluding the virtual objects. For example, when a virtual Roman soldier walks around the paper fort, he needs to appear to walk between buildings and go out of sight as he does so. By creating the virtual model within the gaming-engine, it is possible to use Unity's rendering engine to hide the soldier as he walks behind buildings. In order to achieve this I had to write the program for two custom 'shaders'. Put simply, a shader is a program that tells the rendering engine the correct way to render a specific element when displayed to the user on the screen. In this particular case, a combination of a shader attached to the objects to be occluded (the soldier) and a separate shader attached to the occlusion surface (the buildings) mean that when the final scene is rendered, the shader attached to the soldier tells the rendering engine only to render the parts of its model that are within view of the camera and not those which are behind a building. Due to these occlusion issues, it is important that the physical model and the virtual model are at exactly the same scale, this is achieved by scaling the virtual model so that it overlies the marker image exactly (Figure 16).

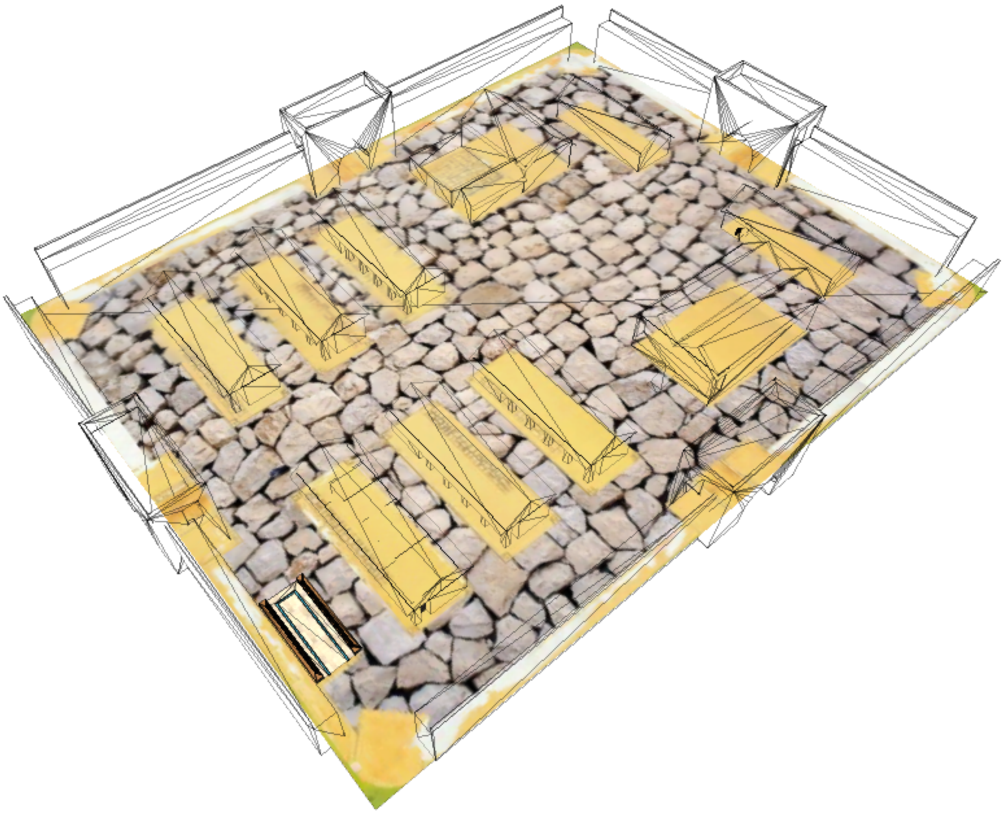


Figure 16 - Virtual fort model overlaying a virtual representation of the marker image

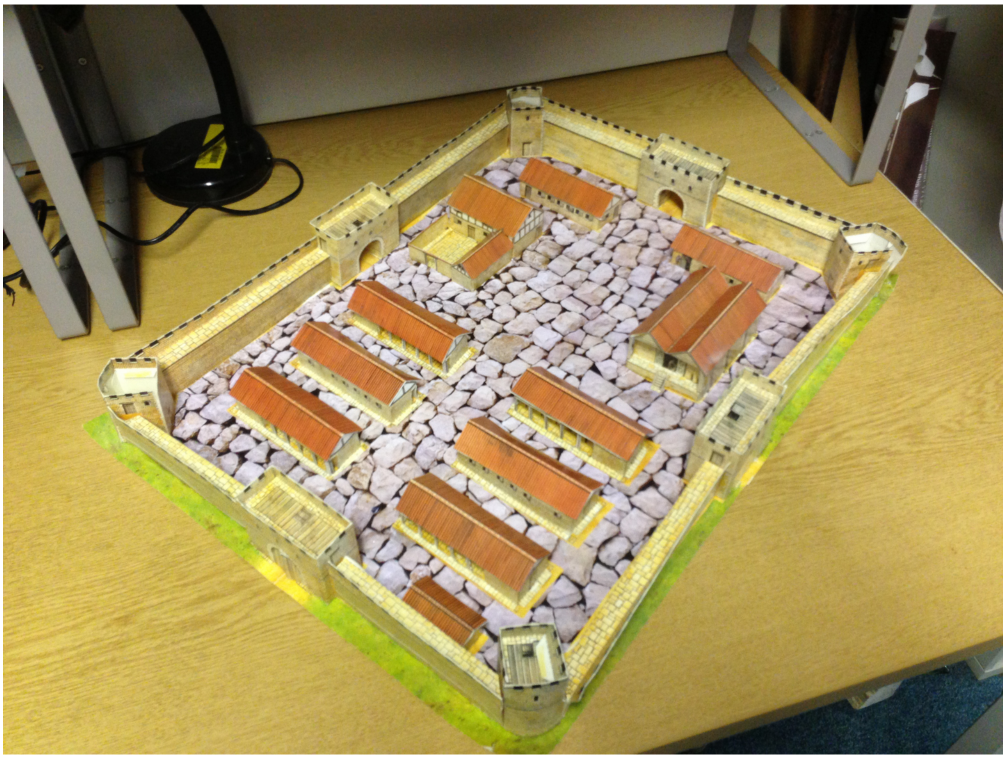


Figure 17 - The physical model of the fort, with the marker image attached

Once the physical fort has been assembled (Figure 17) and the virtual model of the fort built and aligned to the marker image, the code within Unity can be compiled to create an iPad application.

When the iPad application is running, it displays the normal feed from the video on the screen. As the user moves the camera to see the physical fort the application and the image recognition algorithm recognises the image marker and overlays the virtual elements onto screen, so that they appear to be part of the fort itself (Figure 18).

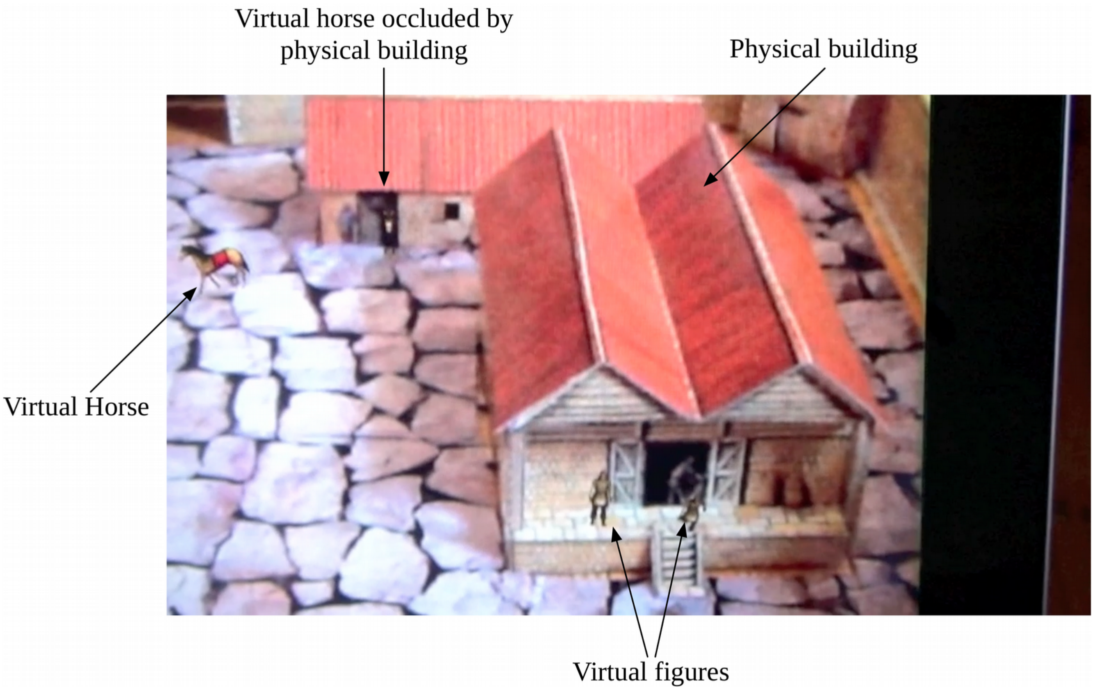


Figure 18 - Screenshot from the FortAR application showing the virtual figures overlaid onto the physical model. As can be seen, the virtual horse in the background appears to be occluded by the virtual stable door.

The virtual elements can be anything from people or horses, as in Figure 18, virtual information 'labels' (Figure 19), or even reconstructions of the possible interiors of the buildings overlaid on the physical model (Figure 20).

Figure 19 - The FortAR application in use, showing a virtual information label attached to the physical model

Figure 20 - The FortAR application in use, showing an information label along with a virtual reconstruction of the interior of a building overlaid onto the physical model. A video of the application in action can be seen at: http://vimeo.com/30861262

This example has shown the various steps needed to create an Augmented Reality experience, and ones which I will build on in Chapters Seven and Eight. The FortAR application represents a large amount of effort in terms of programming and computer modelling (the entire application took nearly seven months to produce). There have been very few other applications of its type, and even as a prototype it provides a level of augmentation to the model that may be desirable in a museums or classroom context. As a direct result of my creation of the application the publishers of the paper fort (Usborne) have expressed an interest in working with me to develop the concept further and perhaps augmenting some of their other 'Build Your Own' lines. It also demonstrates the sophisticated level of augmentation that can be achieved using the relatively low-cost solution of Apple's iPad as the delivery device and Unity3D and Vuforia as the application environment.

However, the AR experience is here limited to a model, and I wish to use AR in a landscape context. Building labels and cutaways provide a useful level of interpretation and the occlusion of the virtual content by the real world allows exploration of how the real and virtual content changes when the viewpoint is altered. This is essential when using AR in a landscape context, as the landscape form needs to occlude and be occluded by the virtual content to ensure a proper analysis of the changing landscape, and how, by moving through it, the archaeological material affects and is affected by the unfolding views.

Now that the terminology and methodology of creating and deploying AR experiences is in place, I will go on to examine some previous uses of AR in archaeology, expanding on some previous case studies.

Previous Applications of AR in Archaeology

Augmented Reality has previously been used for archaeological applications, as the ability to superimpose images or objects from the past into modern-day locations is a tantalising use-case scenario and has been used successfully, most often in a tourism or museum setting. As I explained in the introduction, I am interested in the use of AR as a tool for archaeologists to better explore and interpret an embodied space. There is a surprising lack of archaeological applications that use AR to do anything except present data to be consumed by visitors to sites or museums. There are very few examples in which AR is used as an interpretive tool by professional archaeologists. A number of reviews of the use of Augmented Reality in cultural heritage settings have been undertaken (Liarokapis 2007; Sylaiou *et al.* 2009; Noh *et al.* 2009) and I expand on some of the more significant below.

One of the few applications that use AR for interpretation is the Visual Interaction Tool for Archaeology (VITA) introduced in 2004 by researchers at Columbia University (Benko *et al.* 2004). VITA uses an Augmented Reality interface to aid in post-excavation analysis of the site of Monte Polizzo. They present a system that allows multi-modal engagement with the archaeological data - through use of a head-worn display, a multi-touch projected table surface, speech commands and a tracked glove. As well as the 'world in miniature' mode, where a small-scale virtual model of the excavations is displayed on the physical table-top in the office, they provide a 'life-size-world' mode, which shows the textured and meshed model of the excavation at 1:1 scale within the user's head-worn display. The user's location is tracked and therefore they can walk 'around' the excavation site. By using the tracked glove, users can examine the archaeological finds at their exact locations of discovery within the 3D model. VITA also combines a number of different mechanisms to deal with the various different types of data (2D, 3D, high-resolution, *etc.*) which ensures the data are always shown in the most appropriate way, *e.g.* a Harris Matrix is viewed on a 2D display, whereas the 3D model is experienced using the head-worn display.

Whilst VITA doesn't allow experience of the archaeological site directly *in situ* it does certainly enhance the post-excavation process. Benko *et al.* undertook some limited user experience evaluation which showed that the system was useful – in particular for being able to "connect the temporal relationships of excavated objects (in the Harris Matrix) with their 3D spatial relationships, all while providing contextual 2D information for these objects" (2004, p.7). Forte and Kurillo (2010) also experiment with recreating data from archaeological sites within collaborative virtual spaces, using a form of augmented virtuality to enable remote users to participate in a collaborative discussion of *in situ* remains using video-based avatars.

The SHAPE project attempted to create a “mixed-reality time machine” (Hall *et al.* 2001, p.96) by enabling participants (via location-based AR) to explore the surroundings of a museum and engage on a quest to recover and reassemble a number of virtual pottery fragments distributed in the real world. Applications such as ARCHEOGUIDE (Archeoguide 2010) also move the AR experience out of the computer lab and into the site itself. ARCHEOGUIDE, released in 2001, is an early example of using an AR device to aid in a tourist's experience of an archaeological site. When the tour begins each user is asked to generate a profile outlining what their interests and background are, a personalised tour is then created for that user to follow. The user is given a AR HWD and reconstructions of the ancient buildings are overlaid directly onto the real world (Figure 21).

Figure 21 - The ARCHEOGUIDE application

The Cultural Heritage Experiences through Socio-personal interactions and Storytelling (CHESS) project takes a similar approach - using slightly more sophisticated profiling, users are led on a personalised tour through the new Acropolis Museum, with the AR content being delivered through a handheld tablet (Roussou *et al.* 2013).

George Papagiannakis *et al.* (2004; 2005; 2007) produced one of the best known cultural heritage AR applications, centred on the site of Pompeii. Using a tracked video-see-through HWD and dynamic modelling of the real and virtual world, Papagiannakis and his team were able to insert virtual characters into various buildings within Pompeii and enact a real-time storytelling scenario, using dynamic occlusion of the virtual objects by both the virtual characters and real visitors. The speech engine in Papagiannakis' work also allows interaction from the user - creating a feeling of social interaction with the virtual characters. Although this provides interaction, the virtual characters have pre-defined scripts and therefore the visitor is hearing a story rather than directly engaging in a conversation.

Dekker and Champion (2007) have made some investigation into the use of biofeedback mechanisms to directly influence the experience of video-game playing. They devised a zombie attack game in which the user's heart-rate was monitored and the game's AI-engine adjusted to either ramp-up or calm down the user by introducing more or fewer zombies into the arena and changing the appearance of the game. They conclude that this type of technology can certainly alter the user's affective state, although due to various interface issues its application was somewhat limited at the time of the study. Monitoring and reacting to the user's affective state fits nicely within the Arc of

Intentionality (AoI) and could certainly be a way of increasing the overall feeling of presence.

All of these studies show that the AR experience needs to be somewhat tailored to the user as well as to the environment in which the AR experience takes place. They are playing heavily on the user's affective and social states as outlined within the AoI. It is vital to remember that in any AR experience we are dealing with augmenting an individual's personal interaction with the world and that our experience of the world is unique and, by extension, there is not a one-size-fits-all solution to the augmentation of this world. Whilst some of the applications have been landscape-based, they have been focused on the tourism, storytelling and reconstruction aspects of using AR in archaeology. It appears that, beyond VITA, which is constrained to the computer lab, no application has yet been produced that uses AR to expand our archaeological knowledge or use it as a tool for investigation and exploration of ideas and the production of new interpretations. Instead, previous AR applications have been solely for use for presentation or explanation of existing ideas, essentially a passive experience. I believe that AR has greater potential than this and can be used in an active way as a means of investigation and to find out new things about the past, rather than just to consume existing knowledge. In the next section, I build on this idea and present a new manifesto for the use of AR in archaeology, one that calls for a closer relationship between analysis and experience and harnesses the *in situ* nature of AR to the exploratory power of GIS analysis.

The Embodied GIS

> “Now let us make the fantastic supposition that Rome were not a human dwelling-place, but a mental entity with just as long and varied a past history: that is, in which nothing once constructed had perished, and all the earlier stages of development had survived alongside the latest. This would mean that in Rome the palaces of the Caesars were still standing on the Palatine and the Septizonium of Septimius Severus was still towering to its old height; that the beautiful statues were still standing in the colonnade of the Castle of St. Angelo, as they were up to its siege by the Goths, and so on. But more still: where the Palazzo Caffarelli stands there would also be, without this being removed, the Temple of Jupiter Capitolinus, not merely in its latest form, moreover, as the Romans of the Caesars saw it, but also in its earliest shape, when it

> still wore an Etruscan design and was adorned with terra-cotta antefixae. Where the Coliseum stands now, we could at the same time admire Nero's Golden House; on the Piazza of the Pantheon we should find not only the Pantheon of today as bequeathed to us by Hadrian, but on the same site also Agrippa's original edifice; indeed, the same ground would support the church of Santa Maria sopra Minerva and the old temple over which it was built. And the observer would need merely to shift the focus of his eyes, perhaps, or change his position, in order to call up a view of either the one or the other." (Freud 1946, pp.18–19)

In the quotation above, Sigmund Freud is talking about the mind as a city, a place of ancient history where every experience leaves a discoverable trace. He asserts that this type of vision is impossible to realise within a city because the earlier traces are always wiped out by later events – yet within the mind all of the superficially forgotten traces are remembered. As archaeologists we are constantly looking for the forgotten traces, the elements of the landscape that can remind us of what came before. As I have shown in the preceding section, it is possible to create Freud's palimpsest within a computer environment and even return the Colosseum to its original state (Archeoguide 2010). Pushing Freud's metaphor still further, we can also look at a journey through a landscape as a journey through the mind – rediscovering old memories, representing things either as we want to remember them or as we think things should or could have happened. AR gives us this opportunity, and AR coupled with solid GIS modelling enables us to weave these old/new memories into the landscape we are interested in and answer real archaeological questions. By using this approach I believe it is possible to create what I term an *embodied GIS*.

Although the term 'embodied GIS' was first used in 1993 by Peter Zwart (Zwart 1993), his vision was tied up with the emergence of ubiquitous computing (Weiser 1991). He advocated that in order for GIS to become an accepted and everyday technology it needed to be so ubiquitous that the user did not even know they were using a GIS, it was essential to "…fit [GIS] into the human environment, make it an unconscious part of every day life instead of attempting to mould humans to it" (Zwart 1993, p.197). Effectively GIS technology would be embodied in everything, rather than standing on its own. "The users should remain in the flow of their work and not be disrupted by the spatial or mapping process unless it is the work on which they are engaged" (Zwart 1993, p.202). Zwart outlined four different conditions for an embodied GIS:

> 1. The operation, technology and products of the GIS will provide a background service only. To do this it will need to be totally subjugated to, and subsumed by, the task or process to which it is coupled.
>
> 2. There will be a number of kinds of GIS differing in size, form and function, with most dedicated to performing only a limited but well-defined set of operations on limited and defined types of data.
>
> 3. They will be ubiquitous, having multifarious users, none of whom has a proprietary or usage right to, or necessarily understands the operations of a particular embodied GIS device.
>
> 4. They will be affordable and not noticeably different in cost to other support role technologies.

Zwart's paper was criticised at the time *because* it implied that users of GIS technology did not need to concern themselves with the underlying algorithms, "…just as even sophisticated statistics packages do not relieve the user from understanding possibilities and pitfalls of the methods they offer, also GIS should be designed in a way that elucidates rather than hides or obscures the nature of the data transformations performed" (Wegener 1993, p.207). It is also suggested by Wegener that by hiding these algorithms and the control of the tools that perform them innovation within GIS technology would be stifled (1993, p.207). To some extent, it would seem as if Zwart's concept has already come to pass, with, for example, the ubiquity of the satellite navigation system (SatNav) or Google Maps in the smartphone or computer. The user of a SatNav does not know the complex geographic routing algorithms that are being used to display the quickest route to their destination; someone using the high-resolution satellite imagery on Google Maps does not need to know the advanced image manipulation and transformation parameters undertaken to project the image into the right place and perspective.

Zwart's concept has not been entirely realised either; we still refer to GIS as a separate technology. Indeed, most universities in the UK and the US offer entire Masters-level courses on GIS technology. The classification of GIS as a Geographic Information System or Geographic Information Science has been a fundamental debate since the inception of the term and Wright *et al.'s* classic paper of 1997, *GIS: Tool or Science?*, suggests three positions: GIS as a tool; GIS as toolmaking (i.e. the advancement of the tool's capabilities and facilities); and GIS as a science. According to Wright *et al.*, each of these positions brings with it advantages and disadvantages in terms of research funding and teaching, and they question whether “doing GIS” is simply using a suite of software (GIS as a tool, akin to using a word processor) or undertaking substantive science (GIS as science which may attract more research funding and would be suitable for graduate study) or the position in between (GIS as toolmaking) which advances the technology to enable the science (1997, p.347). This debate inevitably extended into the use of GIS for archaeological investigation (Wheatley 1993; Barceló & Pallarés 1996; Witcher 1999) and is still ongoing (Conolly & Lake 2006, chaps.1,2).

Regardless of the science or tool debate, the ubiquity of spatial technologies currently available is certainly evident (fulfilling Zwart's first requirement), and the size and cost of a spatially-enabled system is certainly affordable today (Zwart's fourth requirement). My concept of an embodied GIS, however, is slightly different from Zwart's, although it does build on his basic concepts. I would argue that in general the spatial functions and algorithms used within a GIS should be invisible during usage. However, they should still be accessible and comprehensible for someone who wants to move beyond simply being a passive user. The ability to see, use or change the algorithms and spatial procedures should be a choice for the user and not just hidden away in the black box. The key part of Zwart's concept for my work is the acceptance that GIS is just another tool in the (archaeologist's) toolkit. Rather than concentrating so much on the technology itself, my embodied GIS is an acceptance that GIS technology is simply a method to enable our evidence to be recorded and explored spatially.

However, currently, this 'space' is represented within a computer environment and viewing it is limited to a screen usually in an office. I want to move this spatial location away from the office and use the GIS technology to give archaeological objects and concepts a place in physical space. I want to be able to explore and use the GIS data *within the space* that is being modelled. This is not an eschewing of GIS, instead it is the enablement of GIS technology to be explored in the way that it always should have been, naturally and *in situ*, which up until now has been limited by the technology. In this way I am taking on the middle ground of the science *vs.* tool debate – I see the creation of the embodied GIS as toolmaking, extending the current theories and technology into a new domain – allowing archaeologists to use the tool to help create new interpretations of their data, and enabling them to undertake an investigation of a landscape while maximising the advantages that computer-based methods bring.

My concept of an embodied GIS, then, is simply this – the combination of traditional GIS technology and Augmented Reality technology – allowing the experience of the GIS data within the field and the ability to feed directly from the field into the GIS. All of the data held within the GIS files should be readily accessible when actually visiting the archaeological site. This does not just mean accessible by taking a laptop out into the field and sitting down with the GIS data, or even using a tablet version of the GIS software. Instead, the data need to be able to be visualised *as if they were directly there in the landscape* – overlaid on the hills, plains and rivers themselves, reacting, developing and changing as one moves through the space. One should be able to walk around the data, through the data and query and update the data. It is a step beyond the blinking red location dot of Google Maps or the entirely virtual world of VR – out of the abstraction of the flat plane digital map or the entirely false rendered 3D world and into the real world. With the limited addition to the landscape of data from the GIS, the landscape itself is being used as a canvas – enhancing the feeling of presence. The introduction of the virtual elements should be kept to a minimum and, in contrast, the landscape itself should provide the bulk of the experience – the way in which the sloping ground tires out your legs; the feeling of shelter gained from standing in the lee of a hill; and the feeling of perspective when vistas open up in front of you as you explore the landscape. As archaeologists we are striving to get closer to what it was to be a human living in the past and these are all elements that have been extremely challenging to recreate within traditional GIS, but are vital to the way humans experience space and what it means to them and which are vital to the experience of that specific landscape.

Overlaying the abstracted models from the GIS on the landscape in question not only emphasises the modelled nature of the GIS data, but allows for constant adjustment to the data themselves to enable it to better fit the landscape and to highlight areas where the model does not fit the real or conceptual landscape that we are trying to create. The embodied GIS also encourages, perhaps even demands, the inclusion of other senses within the GIS dataset. For too long the use of GIS in archaeology has been only about vision (see Lake & Woodman 2003), and the AR interface offers the opportunity to use the other senses when exploring the landscape: the smell of evening meals being cooked on an open fire, the sound of animals being brought in for the night, the everyday things that would be experienced by everyone as they went about their lives. By enabling and demanding the inclusion of these extra senses, GIS users are encouraged to take account of the need for these extra data and to further integrate them into their GIS analyses (see Rennell 2009, chap.9 for a further exploration of these ideas). Without the addition of the other senses – or at least a move toward their integration – the AR experience will seem flat and lifeless, a pertinent reminder for traditional GIS users about the brevity and limitations of their hamstrung datasets.

It is important to remember, however, that the traditional GIS model should not be shunned - on the contrary, the power of modelling within the GIS should be embraced, and the models can be better tested and calibrated by taking them out into the field and overlaying them onto the present landscape. Whilst the landscape can be used as a canvas for the GIS data and adds many features to the experience that cannot yet be easily recreated in a computer environment, it is of course the landscape of the present day. Certain landscapes may not have changed dramatically for hundreds of years, but equally, many current landscapes will be radically different from the ancient landscape. Therefore, the GIS data becomes all the more important in representing the area as it used to be, and the modern-day reality can be augmented or diminished depending on the data held within the GIS model. GIS objects can be placed into the modern landscape at their modelled ancient position – emphasising the differences between the modern and ancient ground surface or environmental evidence can be used to add (or remove) topographic features such as trees or rivers, a live action version of Ghadirian & Bishop (2008). The embodied GIS user would then have the vital situated perspective on their data.

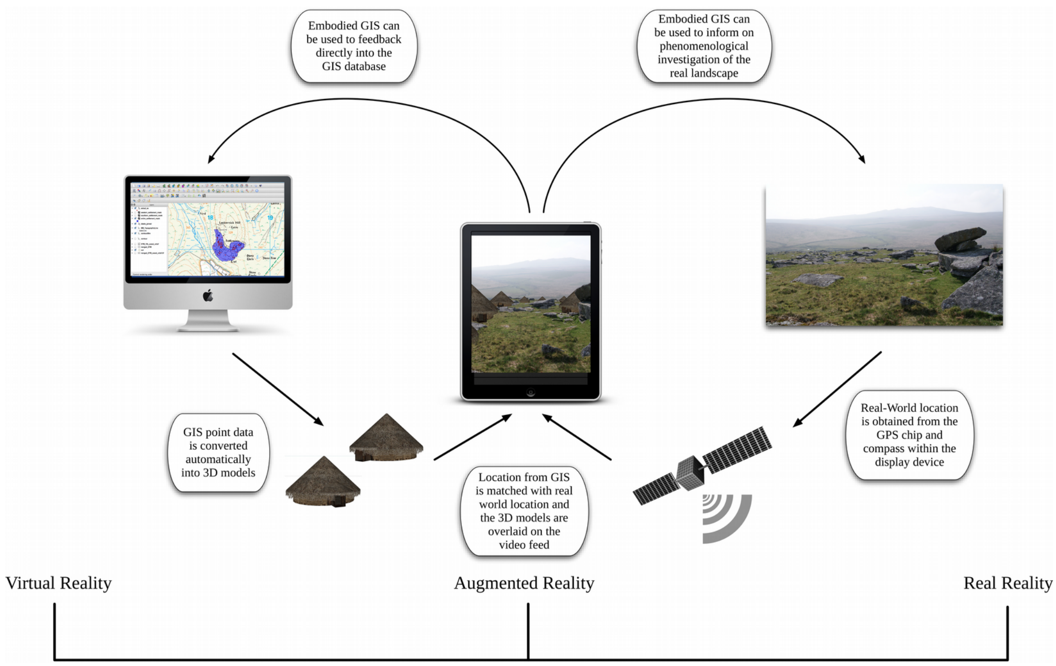


Figure 22 - The Embodied GIS

The embodied GIS should also always be part of a feedback loop, not merely another way of seeing the GIS data. What this means is that in order to be an effective tool, the embodied GIS user should be able to make changes to the data from either the embodied interface or by using the more traditional GIS interface. Both interfaces need to interact with and use the same underlying data structure and datasets. A change made using the GIS interface should be directly updated and experienced within the embodied interface and *vice versa*. That way the strengths of both interfaces work together to refine and improve the underlying dataset. The statistical and computer analysis side of the traditional GIS interface and programs should be allied with the hands-on embodied nature of the AR interface. By viewing the GIS data directly in the landscape, it is possible to make much smaller-scale adjustments to the data, or even add new information back into the GIS dataset, such as the rotation of an object, or the size of an object – the details of which would then be fed back into the GIS attribute table for that object. The embodied user should also be able to add or delete objects from the dataset. The embodied GIS, therefore, is another way into the GIS dataset and a different view on the same data – one that is enriched and informed by the landscape under study itself, that raises questions and challenges the underlying data in the GIS model, and which allows the user to further refine that model and to experience it *in situ*.

Finally, the embodied GIS should be accessible by multiple users at the same time. In the same way that a GIS server can be used to distribute and share data to many users, the embodied GIS should be deployed in a multi-user environment. This allows more than one person to experience the same data at the same time – encouraging reflexivity and multi-vocality, while ensuring that each person is experiencing the same data in the same way – albeit from a different situated perspective. As alluded to in Chapter Two, when discussing and comparing the BiPs of an experience, it is important that the dataset and delivery is the same for each person, to ensure that each person can then respond in their own way to the same affordances, thereby reducing the subjective nature of the discussion. However, if two experiences are not being directly compared, then it would be possible to deliver the dataset using any number of devices. Examples of this may be a simple smartphone screen, a fully-immersive system such as the LifeClipper discussed above (Torpus & Tobler 2011) or perhaps even a remote camera housed on an aerial drone – to enable a perspective not currently available to an earth-bound observer. Care would need to be taken to identify the BiPs of each of these delivery devices on use, however, they would all be interesting and useful ways to explore the basic GIS dataset.

To summarise, then – the embodied GIS as I envision it needs to fulfil at least these following criteria:

1. Combine desktop GIS data with an interface that allows the data to be experienced directly within the landscape in question, using immersive or semi-immersive technology.

2. Encourage the inclusion of the other senses beyond just sight: for example,

sound, smell and touch. Make use of emerging technologies to augment these other senses.

3. Create a feedback loop, so that the embodied interface does not just become a window onto the data; instead it allows two-way data exchange.

4. Be multi-user and multi-device. The data should be able to be explored collaboratively and all users should be able to interact with each other and the data itself. The system should be able to run on multiple types of device.

Throughout this chapter I have explored the practical ways to create augmented reality experiences, and I have demonstrated the creation of such an experience using a paper Roman fort as an example. My review of previous archaeological AR usage revealed a distinct lack of applications being created to facilitate the generation of new archaeological knowledge, with the majority currently being used to present existing knowledge. I believe that this is a great waste of the potential of AR technology and, as Gillings has prophesied for the use of VR in archaeology, AR is also in danger of being used to simply present galleries of photo-realistic reconstructions, instead of being used to expand on and facilitate change in our interpretations of archaeological sites. To offer an alternative to this situation, I have presented my manifesto for the way I believe that AR and GIS analysis should be used together, and the embodied GIS is my suggested way to move towards it. In the second part of this thesis I take all of these themes and apply them to a case study, creating a version of the embodied GIS and assessing its effectiveness within a real archaeological landscape.

Part 2 – Case Study

Chapter 4 - Leskernick Hill

"23rd April 2011 – 10:49a.m. (Lower Trenault Campsite, Nr. Bodmin Moor)
First day of my initial recce visit. We woke up and started to cook breakfast, immediately realising that the infamous 'camping box' was inadequately stocked...
...When looking at an O.S. map to decide where to drive to to enter the Moor – 2 options presented themselves. The closest at Westmoorgate and the second being to walk up from Codda Farm. On consulting Stone Worlds, pgs. 282-284 outline the two routes taken by the team. The surveyors mostly walked in from Westmoorgate, whereas the excavators came in from Bowithick in the north – a route I hadn't even considered. Yet immediately I am drawn to taking that one in opposition to the shorter route PURELY because I am identifying more with the archaeologists than the anthropologists. This is despite not being part of the team and indeed being separated by nearly 7 years from the end of the expedition. 'Tribal Loyalty' is clearly quite strong!" – SJE 2011

In order to illustrate the use of the embodied GIS within an archaeological landscape, I will be using part of Bodmin Moor in Cornwall, UK as a case study, centred around Leskernick Hill. There are a number of reasons why I have chosen Leskernick Hill, some of which I will discuss below and all of which will become evident throughout this and the following chapters. One of the main reasons is that the settlement and ritual complex on Leskernick Hill have been the subject of a major archaeological investigation by a team from University College London (Tilley 1996; Bender et al. 1997; Bender et al. 2007). These investigations included excavation and site survey, along with one of the most famous programmes of phenomenological fieldwork yet undertaken. As I will demonstrate, the rich narrative, fieldwork diary entries, ethnographic analysis, excavation data, radiocarbon dates and finds records of the UCL project provide a rich dataset to begin exploring the embodied GIS. The phenomenological work at Leskernick Hill was the start of the wider development of phenomenological fieldwork methodologies and it seems appropriate to revisit Leskernick now that these methodologies have been further developed, and build on the initial interpretations.

In addition, the archaeological remains of Bodmin Moor as a whole have been intensively surveyed and recorded, providing an excellent record of the monuments and settlements from early prehistory to the post-medieval period (Johnson & Rose 1994;

Herring et al. 2002). This survey has been digitised and made available through the Cornwall and Scilly Isles Historic Environment Record (HER), for use via the internet and within desktop GIS software. There is a wealth of other digital data, including historic maps, digital elevation data and aerial photographs, all of which can also be easily incorporated into a GIS.

Bodmin Moor is likely to have been grazed since the felling of the tree-cover during the Neolithic and this grazing has in places prevented the usual gorse and bracken overgrowth from obscuring the archaeological remains (Pryor 2010, p.68). This, combined with the limiting of modern settlement to edges of the Moor and the prehistoric use of stone rather than wood to construct monuments and houses, means that it contains some of the best-preserved prehistoric landscapes anywhere in Europe.

Whilst Leskernick Hill and its surroundings have been used throughout all periods of history and prehistory, for the purposes of my thesis I will be concentrating on the Bronze Age remains of the Moor. To aid readability a gazetteer containing photographs and maps of the monuments and places mentioned in the the text has been provided in Appendix Two. The following chronological breakdown (built from Webster 2007 and Parker Pearson *pers. comm.*) will be employed:

Period	**From (cal. BC)**	**To (cal. BC)**
Late Neolithic/Chalcolithic	3000	2200
Early Bronze Age (EBA)	2200	1500
Middle Bronze Age (MBA)	1500	1200
Late Bronze Age (LBA)	1200	750

I will first provide some background to Leskernick Hill and Bodmin Moor, then I will discuss the various archaeological interventions and surveys that have been conducted across the Moor and finally I will raise some questions about the Bronze Age occupation of Leskernick Hill and its surrounds, questions that I will attempt to answer in the following chapters.

Background to the Hill and the Moor

Leskernick Hill nestles in the north-eastern part of Bodmin Moor in Cornwall. It is an unimposing hill, dwarfed, over-looked and virtually enclosed by a ring of surrounding hills; as Bender *et al.* suggest, it is the "*omphalos* of the saucer" (Bender et al. 2007, p.32).

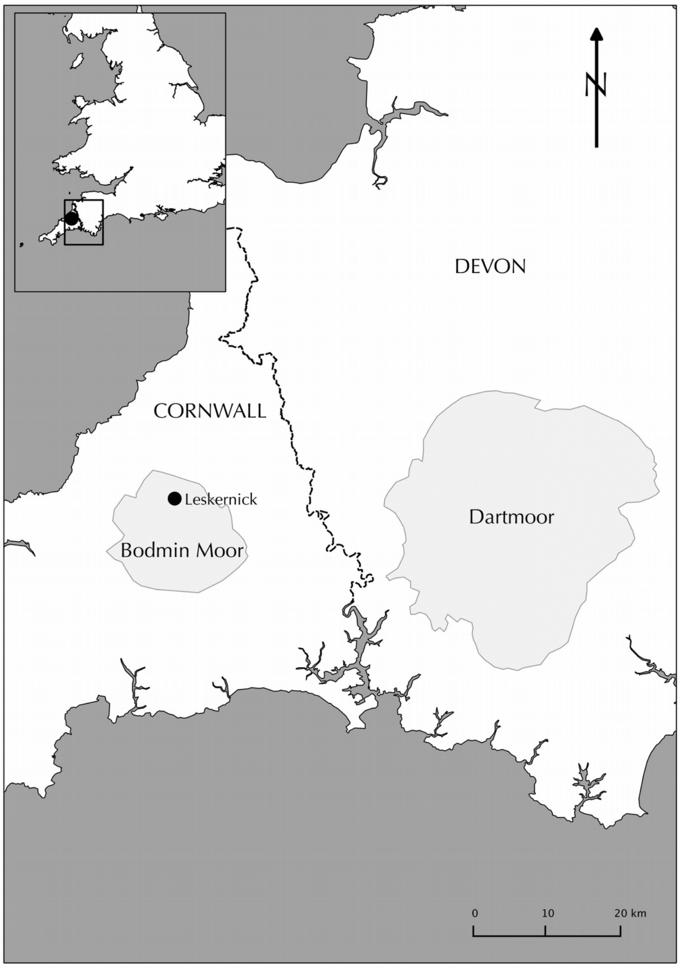


Figure 23 - Leskernick in context

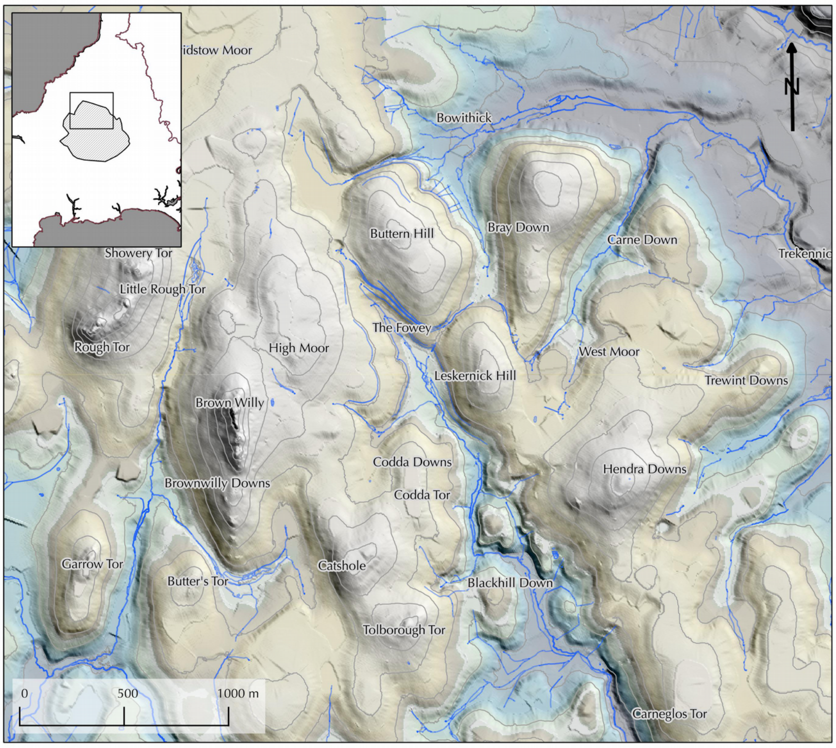


Figure 24 - Leskernick Hill

Leskernick is typical of the rest of Bodmin Moor, situated on a huge lump or boss of various types of granite emerging from the Devonian and Carboniferous age sedimentary rocks. The granites have eroded, creating both the famed tors of Bodmin and also the acidic soils that form the basis of the moorland landscape (Rowe 2005, p.16). The flanks of the hills are covered with 'clitter', overburden that has moved down the hills during the glacial periods or alternatively is a result of a single episode of large-scale frost-shattering of the tors (Bender et al. 2007, p.209). This clitter takes the form of extensive boulder and stone spreads, covering the slopes of the hills and provides much-needed stone for house-building; the sheer amount of it was, however, often a source of confusion for archaeologists (see Bender et al. 1997). Another striking feature of the moorland is the lack of trees; which is no doubt exacerbated by both the blustery winds that continually harry the landscape and modern grazing practice. According to environmental evidence (Brown 1977; Caseldine 1980; Walker & Austin 1985), throughout the prehistoric past, "trees were substantially confined to the more sheltered valleys with the rest of the landscape being dominated by grassland and heath as today" (Tilley 1996, p.163). Pollen analysis of samples taken from the Bronze Age house floors on Leskernick Hill supports this pattern (Bender et al. 2007, p.48). Pollen analysis from other parts of the Moor suggests that the wider landscape was more forested, especially prior to and during the Neolithic (Chapman & Gearey 2000), the consequences of which will be discussed in more detail below. The moor is criss-crossed by slow-moving, meandering streams which run off the granite outcrops and into the marshy areas associated with the softer geology. Leskernick Hill itself sits within the shadow of the highest hill on Bodmin Moor and in Cornwall itself, Brown Willy, whose peak is 420m above Ordnance Datum (AOD).

Figure 25 - Bronze Age Settlement on Leskernick Hill. Courtesy of the Cornwall and Scilly Isles Historic Environment Record.

The archaeological evidence from Bodmin Moor starts in earnest in the Neolithic period. There was earlier activity, but as of 2005 the total number of finds/findspots from the Palaeolithic for the whole of Cornwall was only thirty (Rowe 2005, p.29). The Mesolithic has produced a little more evidence, with Dozmary Pool (Cornwall's only inland lake) being a focus of activity (Berridge & Roberts 1986, pp.28–29; Tilley 1996, p.165). Evidence from the Mesolithic period points to activity also being centred around springheads, marshy areas and the tors themselves (Tilley 1996, p.165). The advent of the Neolithic and Early Bronze Age in the UK brought the construction of various different types of ritual or ceremonial monuments, including long cairns, stone rows, stone circles and hill-top enclosures, many of which are found on Bodmin Moor. As the late Neolithic transitions into the Bronze Age, we also begin to find widespread evidence of permanent and substantial domestic settlement areas, enclosures, fields and cultivation of the land (Tilley 1996, pp.167–168). This pattern continues through the Bronze Age, with approximately fifty round Bronze Age house circles in two distinct settlements on Leskernick Hill by the Middle Bronze Age into the Late Bronze Age (1500-1000 BC) (Figure 25).

Mediaeval and post-mediaeval activity is also clearly evident on Bodmin Moor, through the inevitable farming divisions (field boundaries *etc.*) and peat-cutting, but mainly in the form of tin-working and mining for moorstone. The ravages of this work are seen in the deep cuttings, adits, leats and prospecting pits; when walking through the landscape it is difficult to avoid the evidence of these later workings as, in some cases, vast areas have been excavated for chasing and washing out the tin (Figure 26). It is unclear if tin exploitation was also undertaken in previous eras as the evidence is likely to have been destroyed by the later activity. Bronze Age tin exploitation and the consequences of it for the Leskernick settlement is a subject I will explore more fully in the following chapters. Leskernick Hill itself is relatively free of modern intrusions, with the exception of a small farm building and associated trackways and walls on the southern slopes of the Hill.

Figure 26 - Tin streamworks, used for washing out tin, to the north of Leskernick Hill

Previous archaeological work on Leskernick Hill

The Johnson and Rose Survey

Throughout the 1980s and early 1990s a systematic survey was undertaken of all available aerial photographs of Bodmin Moor, along with targeted ground-truthing. Features in 193 one-km squares were plotted from aerial photographs and surveyed from the ground at scales of 1:2500 and in some places 1:1000 (Johnson & Rose 1994, p.xiii). The result was a gazetteer of all of the archaeological features visible on the ground from the early prehistoric through to the post-mediaeval period. This mammoth piece of work was published in two volumes by English Heritage: volume one deals with the pre-1800 features and volume two with the later periods. The data from the survey was also supplied to Cornwall and Scilly Historic Environment Record (CSHER) and now forms part of their digital record. The Johnson and Rose survey not only identified a large number of cairns (c. 358) and other monumental features, they also identified a total of 1600 hut circles within 211 settlements across Bodmin Moor dating from various prehistoric periods (Johnson & Rose 1994, p.xiii). Johnson and Rose were the first people to provide a detailed survey of the archaeology of Leskernick Hill itself – with a 1:2500 drawn survey of the hut circles and enclosures. Their study has been invaluable to subsequent research on Bodmin Moor, and it has enabled a series of landscape-wide studies to be undertaken. Johnson and Rose numbered each of the huts, the system that was followed by the Stone Worlds team during the late 1990s, and which I also use here.

Stone Worlds

There have been very few modern archaeological evaluations or excavations (especially of settlements) in the north-eastern part of the Moor. The majority of our archaeological knowledge comes from survey projects. Some parts of Bronze Age settlements have been excavated; such as Stannon Down (Mercer 1970) and Roughtor (Thompson & Birkbeck 2009). In both cases the settlements were confirmed to be Middle Bronze Age in date. At Stannon Down the hut circles were built upon a cultivated Neolithic soil, indicating earlier activity in the area. The Roughtor settlement is situated adjacent to a possible Neolithic bank cairn, again suggesting the continued use of the landscape.

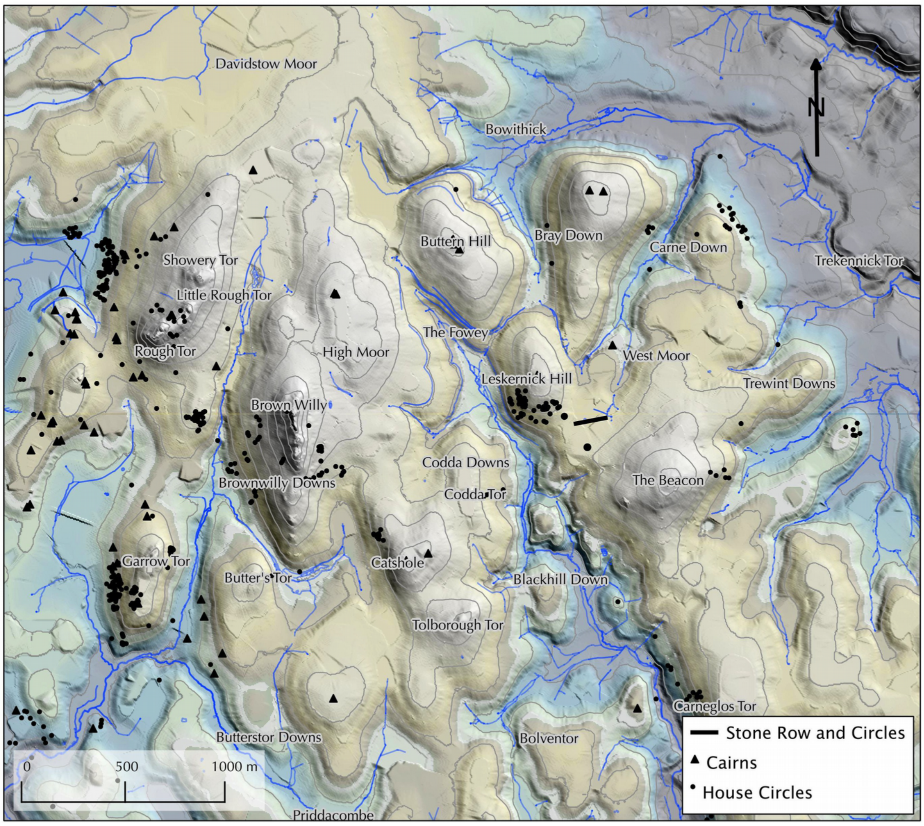


Figure 27 - Bronze Age monuments and house circles in the landscape

One of the few major excavations of a Bodmin Moor settlement was undertaken by UCL in the mid-late 1990s and was of that on Leskernick Hill itself. The first of two planned publications relating to UCL's work at Leskernick Hill, *Stone Worlds: Narrative and Reflexivity in Landscape Archaeology*, was published in 2007 to mixed reviews (Hicks 2009; Barrett 2009; Darvill 2009). It is a multi-disciplinary work covering archaeology, anthropology, public outreach, art and sociology. Envisaged as a book about "... embodied landscapes, about the way in which people engage with the world around them, how they make sense of it, how they understand and work with it" (Bender et al. 2007, p.16) *Stone Worlds* is a brave attempt to present a reflexive approach to the archaeology of the Bronze Age, with specific reference to the settlement and surrounds of the slopes of Leskernick Hill. Alongside the traditional archaeological excavation, the team also explored the setting of house structures and the 'ritual' landscape by way of a number of new and often controversial techniques.

The phenomenological and archaeological work at Leskernick stands as one of the foremost examples of an integrated approach to reflexivity in archaeology and, although this sometimes means that the narrative appears to overflow with mundanity (Darvill 2009, p.264), it does represent a methodology for thinking through the landscape and offering other possibilities that are not always presented in standard publications or are filtered out during the process of interpretation (Bender et al. 2007, p.28). In order to move beyond 'normal' fieldwork practice, the team at Leskernick explored a number of novel ideas that fit nicely with the concepts outlined in my previous chapters and lend themselves well to the integration of a Mixed Reality approach. In the following chapters I will draw on the work undertaken by the Stone Worlds team, and will combine some of their field methodologies with my concept of the embodied GIS to further explore the archaeology of Leskernick Hill.

Stone Worlds: Narrative and Reflexivity in Landscape Archaeology is only the first of two books from the project, with another volume promised that will fully present the results of the archaeological excavation. The basic chronology of the site as outlined by the Stone Worlds team is as follows:

The first monument 'erected' on Leskernick Hill was likely to have been the Propped Stone or Quoit (Figure 28 and see Appendix Two) – which stands just off the crest of the hill. The Propped Stone is a piece of the top strata of the granite tor that stands on Leskernick Hill that has weathered through enough to allow it to be swivelled around to sit at right angles to the main bedding planes of the tor. The stone has then been propped at one end with a pile of stones, to allow light to shine through a gap and to form a skyline feature when viewed from below. The Propped Stone is the first of a number of examples of culturally modified natural features present on Leskernick Hill which, as will be seen, include both ritual monuments (the Propped Stone and the stone row) and settlement features (the backstones of houses and the enclosure walls). This interplay of 'culture' and 'nature' is an ongoing theme within the study of Leskernick Hill and wider Bronze Age studies (see Hamilton et al. 2008; Bradley 2000; Tilley 1996) and is one I will return to throughout this thesis. It is clearly not possible to 'excavate' the Propped Stone and its setting. However, dating using astronomical alignments suggests that it could have been modified in the early Neolithic, or even possibly the Mesolithic

(Herring 1997). The stone is of particular interest because it is aligned so that the rays of the setting sun pass through the hole in the structure on Midsummer's Day.

Figure 28 - The Propped Stone or Quoit, looking west

Herring suggests that the viewing platform for this phenomenon was a probable Neolithic long mound on the lower slopes of Beacon Hill to the east of Leskernick Hill (1997, p.180). A further Neolithic long mound stands on the slopes of Catshole Tor to the south of Leskernick Hill (Herring 1983). The mound on Beacon Hill appears to be essentially an earthen structure, whereas the mound on Catshole Tor is almost certainly a long cairn containing stone elements, presumably with one or more burials within it. Tilley (1996) and Herring (1997) both demonstrate the importance of the alignments of the Neolithic mounds with surrounding tors and also the Propped Stone. Herring also notes a barrow on the flattish ground between Leskernick Hill and Beacon Hill and, according to him, this forms part of the alignment between the Beacon Hill long mound and the Propped Stone. Bender *et al*. dismiss this barrow as a “large mound” and a result of “much later mining activity” (2007, p.86); however, true to their reflexive aims they do also present Herring's alternative interpretation as a footnote. Without excavation it is difficult to say whether or not this is a prehistoric feature, but as I noticed on a recent visit, its orientation and shape do resemble somewhat the distant Brown Gelly Downs, which may indicate its status as an intentionally shaped barrow (Figure 29). This mound remains problematic for the Stone Worlds team, because it may represent one of the very few examples of a low-lying mound on Bodmin Moor – however, as they did not consider it to be prehistoric, it is unclear how the mound would fit into their thesis of the site's development.

Figure 29 - The possible barrow below Leskernick Hill, looking south. Note the resemblance to Brown Gelly Downs in the far distance

Following the construction of the Neolithic mounds and the modification of the Propped Stone, two stone circles and one stone row were erected in the flatter ground between Leskernick Hill and Beacon Hill. The 'Great Cairn' (Figure 30), a large multiple-kerbed cairn, is presumed to have also been constructed around the same time on top of Leskernick Hill itself. Although unexcavated, by using comparanda from Bodmin Moor it is suggested by Bender *et al.* that the area of the Great Cairn began as a ceremonial area that was later enclosed with a stake circle or stone settings. Following this initial phase the cairn itself was erected over the ceremonial setting, “sealing it off and creating a noticeable marker in the landscape that served to remind people of the activities that have taken place” (Bender et al. 2007, p.86).

Figure 30 - The 'Great Cairn' on the top of Leskernick Hill, looking north

The stone row and circles are a unique set of ritual monuments for Bodmin Moor, as they occur in such close proximity of each other. Bender *et al.* describe the stone circles and row thus, “today, the stones of the stone row and circles are ruinous, indistinct, and grass covered. But even when they were first set up, they would have been modest. With the exception of the recumbent stones at the terminal of the stone row, hardly any are more than 0.5m high” (2007, p.87). The row is 317m long running ENE-WSW; there is a terminal setting comprising three stones at the WSW end, but the ENE end is not clear and the row could easily have been longer (Herring 1997, p.179). Excavation of the terminal setting by the UCL team showed that the three terminal stones would have been erected in ascending order and therefore much more visible in the area than the smaller stones of the row itself. Due to the current virtual invisibility of the stone row, during excavation, the UCL team used small red flags to demarcate the locations of each of the stones. The flags apparently helped to “invigorate” the stones, enabling them to become “stones by which to learn, by which to remember, by which to orient, and by which to think” (Bender et al. 2007, p.100). This type of alteration of the landscape to explore the hidden or invisible meanings is typical of the *Stone Worlds* project, and something I will build on in the following chapters.

The two stone circles are approximately 350m apart, made up of low and indistinct stones. A radiocarbon date from the northerly stone circle dates it to between 1750 and 1540 cal BC, placing it in the latter half of the Early Bronze Age. It is unclear if the circles and row were built at the same time, but it is presumed that they are roughly contemporary. The northern stone circle has a recumbent stone at the centre, which the *Stone Worlds* team suggest was not originally a standing stone, but instead an earth-fast boulder that was levered out of the ground and then skewed around to lay in a different direction (an example of a culture-nature modification). They suggest that, even if it were once standing, it would not have been in the middle of the circle, but approximately 9m off-centre (Bender et al. 2007, p.104 and footnote 4.7).

As well as the built monuments or modified natural features (the Propped Stone), Bender *et al.* place great emphasis on the form of the land itself, suggesting that the tors and hills themselves were imbued with ritual significance. They pay particular attention to Brown Willy (to the west of Leskernick Hill) and Roughtor (behind Brown Willy to the west of Leskernick Hill) suggesting that due to their size and shape they would have had particular significance in the landscape. However, they also emphasise that any of the other hills could have also been of significance to the inhabitants of Leskernick Hill (Bender et al. 2007, chap.2).

Bender, Hamilton and Tilley suggest that only once the ritual elements of the landscape were in place did the settlement on the Hill occur. “Indeed, they probably settled at Leskernick precisely because these ritual places already existed or, rather, because the presence of these ritual places indicated that Leskernick Hill was an ancestral place of great and deep significance” (Bender et al. 2007, p.82).

The settlements on Leskernick Hill

The settlements, comprising a mixture of house circles and enclosure walls, take the form of two distinct areas, one on the southern side of the hill and one on the western side. It is unclear which side of the hill was settled first, although the earliest radiocarbon date (1430-1265 cal BC) comes from the southern settlement. Herring suggests that the enclosures and settlement on the southern [eastern] side of the hill were established after the stone circle, as they are arranged in a respectful arc - “as if the fields, the secular creations on the hill, should not encroach too far onto an area used more for ritual or ceremony” (1997, p.179). Bender *et al*. agree with this view, asserting that there was likely a small time-lapse between the creation of the ritual landscape and the more domestic settling of the hill.

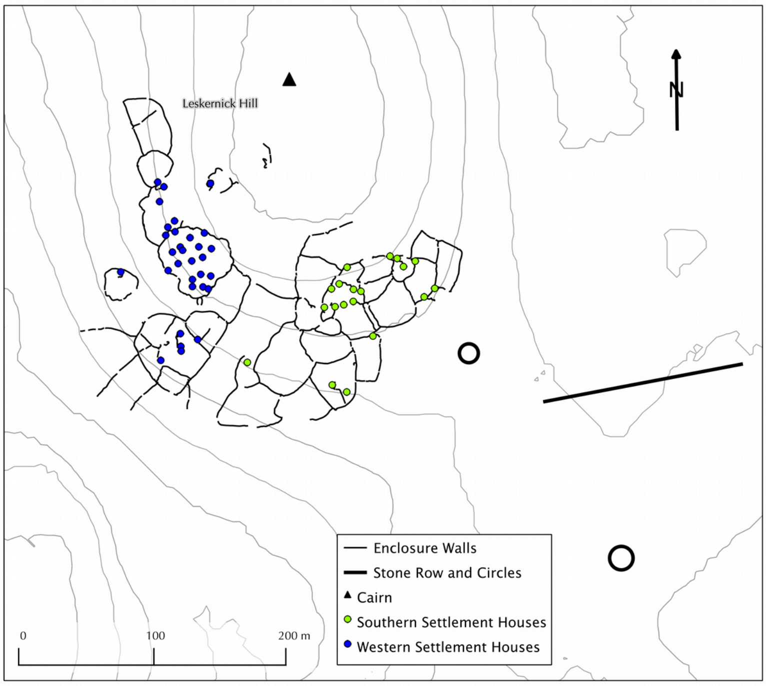


Figure 31 - The settlement of Leskernick Hill

The sequence of occupation and abandonment would appear to be quite complex throughout the Middle to Late Bronze Age on Leskernick Hill. Each individual house or structure quite rightly has its own history, some of which I will unpick in the following chapters. From the evidence provided by the excavation and survey work, the settlements appear to have been built up over a “few centuries”, eventually housing somewhere between 100-200 people at their peak (Bender et al. 2007, p.158). The two settlement areas are arranged into quite close-set households, with further groupings of houses. It is important to note here that these houses, although being arranged in rough circles or 'enclaves', have doorways which do not look in on each other: instead they almost exclusively face south or south-west. There are notable exceptions to this rule, which will be discussed later, but the general pattern is to look down the hillside, away from the prevailing wind. As time passes (into the late Middle and Late Bronze Age) the settlement pattern changes to a series of isolated houses that span both sides of the Hill. It is unclear if all of the houses on the hill were in use at the same time; this is considered unlikely instead, the houses were in a constant flux of use, decay, repair, reuse and abandonment. As with other Bronze Age sites in Britain, some of the houses were 'ritually closed' and converted into cairns (Nowakowski 1991; 2001; Brück 2001). The Stone Worlds team poignantly paints the picture thus: “... there was a period when the family households packed up and moved away, leaving just a few members of the community who continued to return during the summer months to mind the herds. Then, sometime before the beginning of the first millennium BC, even they stopped coming” (Bender et al. 2007, p.200).

Leskernick in a wider context

It is worth a pause at this point to briefly examine the overall settlement pattern of the south west of Britain, when compared with other Bronze Age settlement in southern Britain. The 'classic' representation of Bronze Age activity in southern Britain is a core/periphery model, in which the Early Bronze Age elites were centred in the settlements of Wessex (characterised by richly attested burials and major ritual centres, such as Stonehenge) which then slowly moved out into the upland areas of the Moors, seeking new areas for exploitation (see Bradley 1984; Bender et al. 2007, pp.418–428); all of which formed part of a wider European core/periphery system (see Gilman et al. 1981 for discussion). Following this model, we could argue that the individuals that settled on Leskernick Hill were driven there because of population pressure on the lowlands, and so were forced to colonise the less favourable uplands. In terms of the wider social structure in the core/periphery model, it is possible that a local elite (perhaps the person buried within the famously rich Rillaton burial, approximately 15km southeast of Leskernick) was controlling the supply of local tin and raw materials and exchanging them for finished goods with the chieftains in Wessex.

Bender *et al.* (2007, pp.418–428) provide a robust rebuttal of this entire model, and indeed were part of a wider move away from the core/periphery model to one that considers individual context and regional variation (see papers in Brück 2001 that discuss this). Based on an analysis of the variety of artefact and pottery styles from the south west they suggest that instead of trade being directly transacted through the elites of Wessex, the inhabitants of the south west are more likely to have traded in many directions, "... to the Atlantic seaboard, the Cross Channel zone and *sometimes* to Wessex" (2007, p.420; and see Parker Pearson 2005, pp.100–105). They compare the pattern in the south west with the domestic structures to the Deverel-Rimbury tradition (the main settlement pattern within Wessex; see Barrett et al. 1991; Brück 1999), characterised by enclosed settlements, roundhouses, a wide range of domestic pottery, cremation cemeteries, and overt land division, and conclude that the Middle Bronze Age pattern in the south west is remarkably similar, with the exception that in the south west, the settlements are often larger, and placement of the houses and land enclosure is more complex. The general pattern of the Deverel-Rimbury tradition is a single farmstead comprising of a major dwelling and one or two ancillary buildings (Ellison 1981; Parker Pearson 2005, pp.99–100). This pattern is also generally representative of the lowlands of the south west, but is not always present and the Trethellan Farm settlement near Newquay in Cornwall is a lowland settlement, but is an arrangement of seven dwellings with ancillary buildings within a separate area of the site, more resembling a hamlet or small village than a single farmstead (Nowakowski 1991).

The pattern of settlement on the uplands of Bodmin Moor is different, in that the settlements comprise a much larger number of houses and the living style appears to be more communal (see examples at Leskernick Hill [Bender et al. 1997]; Craddock Moor, Garrow and Stannon on Bodmin Moor [Johnson & Rose 1994]). Rather than a house being used by a family for a single generation and then closed as in the wider pattern for Southern Britain (see Brück 1999), the Leskernick houses would appear to be repaired often and have a longer use-life. In addition, rather than just finding domestic buildings, ancillary structures and animal structures as in the Wessex examples, the upland settlements also contain what have been interpreted as built ritual structures within the settlements that may have acted as loci for everyday rituals (Nowakowski 1991; Jones 1999; Bender et al. 2007). Bender *et al.* interpret this as evidence that the lowland communities were creating new settlements on the chalk downlands of central southern Britain, whereas the upland communities of the south west were settling within areas of earlier ancestral monuments:

> "The downland settlements go hand-in-hand with new patterns of land tenure (Barrett 1994), whereas the upland sites mark places and landscapes of ancestral veneration, communal gatherings, and burials. What is new in these south-westerly contexts is the layering of a ritual cosmology at different scales to bind daily practice into the wider ancestral patterns preset by the form and positioning of the Neolithic and earlier Bronze Age cairns, stone circles and stone rows" (Bender et al. 2007, p.426)

Therefore, rather than an abrupt colonisation of the uplands being forced upon the people of the Middle Bronze Age south west, it can be argued that the upland settlers were simply continuing what had gone before, which "suggests highly stable and conservative societies, rather than pioneer communities taking up virgin ground" (Bender et al. 2007, p.421). However, if there was no population pressure, the question remains as to why they made the move.

Why settle the uplands of Leskernick Hill?

As I have already discussed, the uplands of the south west were certainly in use during the Mesolithic, Neolithic and Early Bronze Age – but the only evidence we have of this from Leskernick Hill are the ritual monuments, there is currently no direct evidence for settlement until the Middle Bronze Age. It is likely that the area was previously being exploited as seasonal grazing grounds, but as Bender *et al.* have shown, the area was also highly charged, as evidenced by the ritual monuments. It is tempting to imagine that the Propped Stone, aligned with the sunset on Midsummer's Day, was used by transhumance farmers to celebrate the yearly ritual of bringing their herds to the upland pastures. However, it is possible that there was an earlier settlement on the Hill. The lack of evidence for this earlier settlement could be a result of differential survival of archaeological remains. The MBA settlements on the moorlands (in contrast to the examples surviving in Wessex) are built using stone which, as will be seen, means the foundations and lower courses of the houses survive remarkably well. However, earlier dwellings may have been built entirely from wood, meaning that without careful excavation of vast areas of the Hill, the traces from the postholes might not be visible. Furthermore, the moorland has notoriously acidic soils, meaning that the extent of surviving organic evidence is extremely limited.

It has been suggested that the change from seasonal transhumance exploitation to (semi-)permanent settlement could be attributed to the Neolithic clearance of woodland, resulting in more area available for the planting of crops. However, as I will discuss below, the field systems associated with Leskernick do not appear to be arranged for intensive agriculture; and, as discussed above, the pollen evidence suggests that the moorland surrounding Leskernick Hill was relatively tree-free, even in the Neolithic. In addition, if this were the reason for a change in settlement patterns, we might reasonably expect to see the Wessex pattern of individual farmsteads, rather than large numbers of roundhouses in a single settlement. Fitzpatrick *et al.* in their research framework for the south west, suggest that the model was simply a more developed seasonal pastoral economy (2007, p.120). However, Bender *et al.* attribute the change to two factors: first, a desire to create stronger and closer links with the ancestral places and lay claim to these areas (Bender et al. 2007, p.428; and c.f Bradley 1998, pp.89–92); and second, to lay claim to and exploit the raw materials of the moorlands – such as stone, tin and other minerals (Bender et al. 2007, p.422).

Questioning the Hill

The story of the hill is much more complicated than I have outlined here, and I will develop and further investigate various sections of the history of the site in the following chapters. The discussion of the work of the *Stone Worlds* team and the wider settlement patterns of southern Britain shows that many questions still remain unanswered about the nature and purpose of the settlements on Bodmin Moor – not least those on Leskernick Hill.

The Ritual Landscape, and the origins of the settlements

One of the primary questions that arises concerns the sequence of events that led to the settlement of Leskernick. The settlement itself is divided into two parts, the older being nearest to the stone circles and row, with the later houses built on the western part of the Hill – in a seemingly closer relationship with the settlements on Codda Tor and the views to Brown Willy and Roughtor (Figure 27), but also nearer to the river and springs.

The ritual monuments existed throughout the settlement period (and persist today), therefore, it is important to ascertain what relationship the settlers had with the monuments. The Propped Stone on top of Leskernick Hill was modified at an early stage, and as well as the stone row and stone circles already discussed, cairns were likely already dotted on the tors surrounding the Hill including perhaps the Great Cairn on the top of Leskernick itself. There are no hard and fast dates for the Great Cairn; however, its form and structure suggests a broad date of the Early Bronze Age; but it has not been excavated, and so, like most of the monuments on the Moor, it is difficult to date accurately (Johnson & Rose 1994, p.24). As with the stone row and circles, the date of the construction of the Cairn has implications for the purpose of the original settlers.

The *Stone Worlds* team suggest that there was a "small time lapse" (Bender et al. 2007, p.82) between the building of the northern stone circle and the first settlement house, but how long was this? The radiocarbon ranges suggest there would have been a *minimum* of 110 years or they could be as much as 485 years apart (the stone circle is dated to 1750-1540 cal. BC and the earliest date from within a house is 1430-1265 cal BC [Bender *et al.* table 4.1]), but were other houses in the settlement built earlier than the one excavated? Or were there contemporary houses built of organic materials, that are lost to the archaeological record? It may simply be the case that the more robust building techniques of the Middle Bronze Age have survived better than the more transitory or ephemeral evidence of the earlier usage, so we are left only with the larger monumental structures from the earlier period. If this were the case, then instead of Leskernick being a ritual landscape that evolved into a settlement, it was always inhabited, and used for both ritual and domestic purposes contemporaneously. If, on the other hand, there were no earlier settlements (Neolithic/Early Bronze Age) then where did the people who built the monuments live, and why did they choose this place to erect them? Perhaps it was an area for pilgrimage, or reserved for the dead.

If the gap were longer, more akin to the minimum period of time suggested by the radiocarbon dates, then could the people who built the stone houses here have been the descendants of the monument-builders, who remembered from their childhoods the rituals, or who were part of an established oral tradition that related the stories of the ritual landscape? In this case, the monuments, either understood or partially understood, might seem like waymarkers from earlier generations, pointing to significant features in the landscape; an astronomical calculation device left by the earlier inhabitants (Wood 1978); or perhaps even they indicated, respected and reified the tin deposits under the ground and in the streambanks.

Or was the time-lapse longer, from the far ends of the radiocarbon date range, *c.* 450 years: long enough to forget the people who built the monuments here, forget their purpose, and long enough for completely new people to arrive? If the settlers respected the monuments but took no part in their construction, was it these monuments that brought them to the place, or something else? At any rate, a period of time between the initial, ritual use of the site, and the subsequent building of the settlement implies to Bender *et al.* that the people, "…probably settled at Leskernick precisely because these ritual places existed" (Bender et al. 2007, p.82). The inter-mingling of the rituals and monuments concerning the living and their dead ancestors is well-known throughout the Neolithic, as shown by Parker Pearson *et al.* in the Stonehenge Riverside Project (2006; Parker Pearson 2012) and the observed close proximity of burial cairns to settlement areas and domestic pottery styles found in funerary contexts shows that this pattern continued into the Middle Bronze Age (Bender et al. 1997; Brück 1999; Brück 2001). As will be seen throughout this thesis, GIS, phenomenological techniques and mixed reality all have their roles to play in approaching these problems.

However, it is possible that the settlers of Leskernick arrived in search of better grazing grounds, or of newer and greater sources of tin. Perhaps they came over the rise of Brown Willy from the settlements on the slopes of Roughtor, a breakaway group putting down new roots away from the main grazing grounds, on the outside of the Leskernick bowl. Were they making the conscious decision to settle in a space already demarcated as ritualised and ancestral? Or did they erect the cairns, stone row and stone circles as part of their own ritual and ancestral practices, honouring their own ancestors? There are quite different social behaviours involved in the decision to settle in an acknowledged ancestral/ritual landscape or those to settle somewhere new and build that ancestral landscape around one, and these questions must remain in our minds as we explore the settlements themselves.

House Morphology

The house morphology in the Leskernick settlement itself is quite varied, with some dwelling places, some associated ancillary buildings, animal pens, storage huts, but also some possible open-air shrines and other structures of a more 'ritual' nature. House 3 and House 28, one part of the southern settlement, the other associated with the western, stand aside from the other houses: – Bender *et al.* name these 'shaman's houses', places of distinct ritual significance, with reserved views of the local tors from their doorways. The dwelling places themselves are varied in terms of size and position on the hill. What was the relationship between the houses and the ritual monuments? Moreover, if houses deteriorate or are eventually 'ritually closed' (see Brück 2001) how does this affect the rest of the settlement?

What do these observations suggest about the make-up of the settlements and the social structure or hierarchy within them? If it is presumed that the shaman's houses were indeed of special significance this implies that there was some hierarchy in place that prevented houses being built near the isolated buildings – that the experience of living and working on the hill was different for different people, with certain views, areas or experiences reserved for a privileged few. Not everyone on the hill would have had access to the same experience – how do we break this down to examine more closely what an individual experience would have been like and how this would vary across the site?

A number of themes, therefore, emerge from the previous investigations of the Moor which I will explore in the rest of this thesis. Central to the discussion is the interplay and tensions between the ritual, domestic and industrial aspects of the settlement. The ritual landscape, that is, the elements of the Hill that are traditionally recognised as being used for ritual or ceremonial purposes, includes cairns, stone circles, stone rows, *etc.*; the domestic landscape consists of the houses and enclosures that make up the settlement itself; and the industrial landscape of Leskernick Hill are those that could be considered of an industrial nature, the tin streaming sites, the 'storage' buildings, *etc.* These three aspects of human existence are the traditional way of talking about a settlement (Bradley 2005), and provide a neat way of delineating the discussion. However, were there areas of the site that were more focused on ritual activity and if so how did these relate to the more domestic areas? Where do the tin resources or the agricultural grazing areas fit into this model (if at all)? Herring suggests that the 'ritual' areas on the top of the Hill may have been grazed (1997). Are the ritual aspects related to the tin deposits; does the presence of tin add an extra level of significance to the Hill and its surroundings?

However, as Bradley has explored, the boundaries between ritual, domestic and industrial processes are blurred, "ritual and domestic life went together throughout the prehistoric sequence and it is wrong and – more than that – it is impossible to separate them now" (Bradley 2005, p.210; and see Van Hove 2004). Following Ingold's definition of the *taskscape* (Ingold 1993, p.158), Leskernick Hill is not just a series of topographic features, interspersed with evidence of human occupation, it is an array of related features, both topographic ('natural'?) and human, which provide echoes of the array of activities or tasks undertaken by the previous occupants; indeed, these are even echoed in the tasks undertaken by myself when investigating Leskernick for this research.

These tasks take many forms, washing, herding, building, talking, listening, walking, praying, hunting, gathering, smithing, tin streaming, processing, *ad infinitum*; and to arbitrarily pick these tasks apart, categorise them into boxes and consider those boxes individually is perhaps doing a disservice to the people under study and likely obfuscating the subtler connections between these three areas of activity. It is also very likely to artificially create divisions where they were not discerned in the past (Bradley 2005, chap.7). In the following chapters therefore, I have attempted to acknowledge the "mutual interlocking" (Ingold 1993, p.158) of the activities, monuments and the landscape and, without going so far as to define specific taskscapes, I have taken the concept of the taskscape as inspiration. I argue that the ritual, domestic and industrial landscapes of Leskernick do not and did not exist independently of each other, and the monuments, structures, and landscape features that I have assigned to each category are done so largely for convenience and readability, rather than necessarily as representing the way in which the inhabitants of the settlement on Leskernick Hill thought about or experienced their world.

Moreover, the landscape surrounding Leskernick Hill is home to a vast number of monuments that one could classify as having a ritual meaning or purpose. Taking the Historic Environment Record (HER) data as a catalogue of the known archaeological features, within a 10km search radius of the settlements on the Hill itself there are a total of 214 cairns, two stone circles and one stone row. In addition to this, some other ritual features were identified by Johnson and Rose that have not been added to the HER, including a number of cairns, at least one propped stone (known as quoits in the south west) and a stone row at the western foot of Buttern Hill. These are just the ritual monuments created or formed by human intervention, and the HER does not take account of the natural features that could be regarded as part of the ritual landscape. As Bender *et al.* (building on a wealth of ethnographic literature) suggest, "…the land is regarded as an ancestral creation and striking 'natural' features, be they mountain peaks, unusual rocks, caves, springs, lakes, rivers, bogs, or large trees are sacred places" (2007, p.81; and see Bradley 2000).

This leads on to questions about the actual experience of the site when moving around the structures. Did everyone on site have the same experience? Or did the experiences change dependent on location and outlook? Finally, what decision-making processes were in place when choosing to settle on Leskernick itself and indeed what processes moved the inhabitants to leave? How does this relate to the wider settlement pattern across the Moor and to the contemporary settlements? What is the possible relationship between Leskernick and the settlements at Roughtor or Brown Willy?

In the following chapters I will examine these themes and questions using a variety of techniques. In Chapter Five I use a GIS approach to analyse the landscape and a number of the views from the individual houses and settlement. Using a combination of 'traditional' GIS techniques, alongside some more innovative methods I have developed, I investigate the possible differences between the two sides of the Hill and how they may relate to the cultural and natural features as well as to the landscape as a whole. In Chapter Six I examine the past phenomenological fieldwork that has been undertaken within the Leskernick landscape and present the results from my own phenomenological fieldwork, and demonstrate what insights the approach can have for the core themes outlined above. Finally, in Chapter Seven I will show what further insights can potentially be gained by combining the GIS and phenomenological approaches using the embodied GIS.

Through undertaking these three different methods of analysis I aim to provide answers to a number of questions I have raised throughout this chapter. As I have shown, the Middle Bronze Age pattern of settlement on Leskernick Hill and the uplands of Cornwall is quite distinct from the settlement pattern of the lowlands or of the rest of southern Britain, and by analysing the site in a number of different ways, I hope to demonstrate not only what each technique can bring to further our understanding of Leskernick Hill, but also show what implications this may have for our wider understanding of the Middle Bronze Age across southern Britain and beyond.

Chapter 5 - The GIS Approach

As I have shown in the previous chapter, the prehistoric landscape of Leskernick Hill and Bodmin Moor poses a number of interesting questions that can be addressed in a number of ways. Throughout the following chapters of Part Two I will use a variety of methods - computational, phenomenological and mixed reality - to seek some answers to the questions posed. This chapter concentrates on the computational approach. By using a combination of viewshed analysis and some pioneering spatial statistical methods I will investigate the reason for the placement of the settlement on both a micro-scale (*e.g.* individual house placement) and a macro-scale (*e.g.* landscape scale).

I will first introduce the GIS dataset that I have assembled for the site and the data which I will use for the rest of this thesis. I will then introduce viewshed analysis and discuss some of the advantages and disadvantages of this approach. Following this discussion I present the results of a programme of viewshed analysis that I have undertaken on the Leskernick Hill landscape. Moving beyond the established methods of viewshed analysis, I then introduce a number of new methods to test the statistical validity of the viewsheds and also to investigate areas of the landscape in an innovative way, using 'spatial confidence mapping' and 'visibility fields'. I then proceed to use them to demonstrate a number of possible reasons for both the micro and macro placement of the houses on Leskernick Hill, with particular reference to the industrial landscape.

The Basic Dataset

No GIS analysis of Leskernick Hill has been published previously. However, there are a number of different published and unpublished sources that have been digitised or that I have digitised myself in the process of my research. I defined the study area as a 10km by 10km square centred on Leskernick Hill. This region incorporates the majority of Bodmin Moor and a portion of the surrounding landscape, including settlements and monuments. It was necessary to limit my dataset mainly for data-handling and management reasons, and the 10km area seemed appropriate: incorporating enough of the landscape, but not so much as to render computationally heavy spatial analysis impossible. Restricting the study area did not have any noticeable effect on the majority of my analyses and where it did (for instance the 'edge effect' of some visibility analysis) I discuss the consequences in the appropriate section below. Whilst some of the datasets expand beyond this limit, I have taken the 10km square as the limit for any analysis (Figure 32).

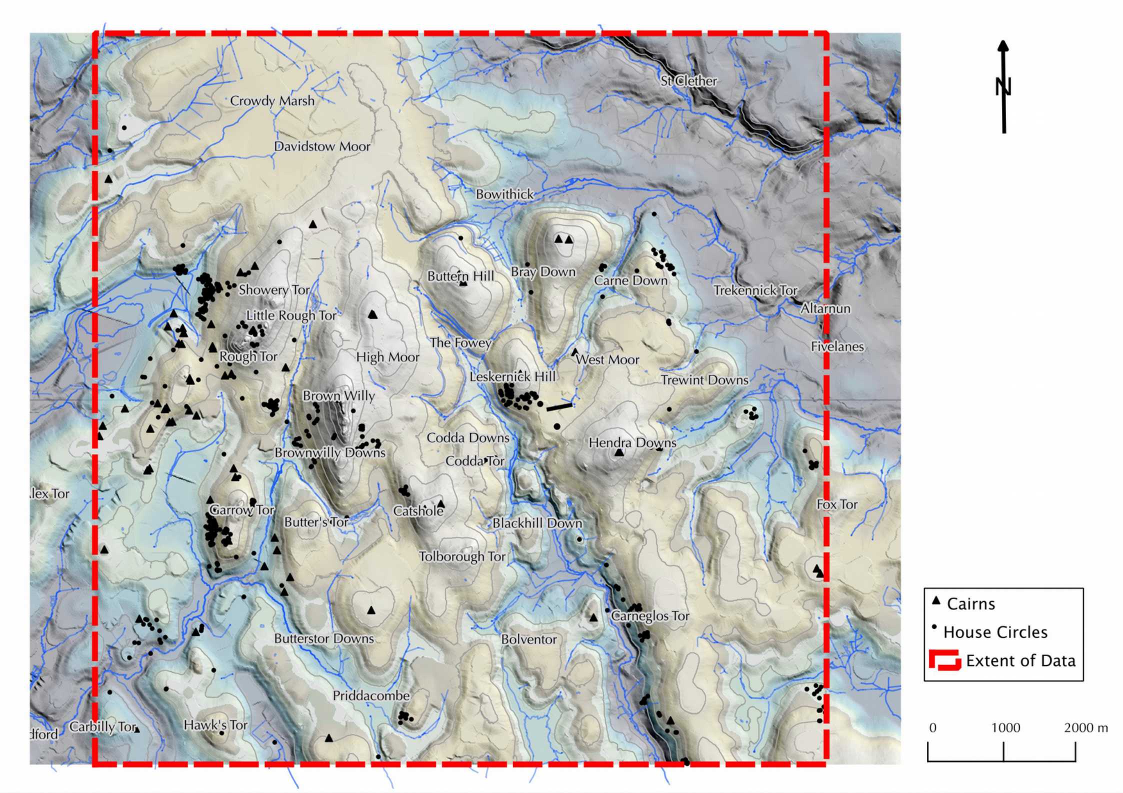


Figure 32 - The study area

For my basic background mapping, I use a combination of the Ordnance Survey 1:10,000 raster map (Ordnance Survey 2009a) and the OS MasterMap vector mapping (Ordnance Survey 2009b). The raster map is supplied in a TIF format already georeferenced to the British National Grid by the Ordnance Survey and I mainly use it for easy navigation within the GIS software and for illustrations. The MasterMap Topography layer is a set of vector files encoded in Geographic Markup Language (GML) (v 2.12) and captured at a scale of 1:1250. The combination of points, lines and polygons with their associated attributes was used for more detailed navigation and illustration. In some areas where the data was missing from other sources (for instance, some of the surveyed enclosure walls), I directly retrieved the features from the MasterMap data.

The best resolution Digital Terrain Model (DTM) of the entire study area was the Ordnance Survey's Landform PROFILE DTM product which is a raster digitised from contours at 1:10,000 resulting in a digital DTM with a horizontal pixel resolution of 10m and a vertical resolution of 10cm in moorland areas (Ordnance Survey 2001, p.3.9). Although the vertical resolution is relatively high, the data are only accurate to +/-5m, which needs to be taken into account during any analysis; in addition, the original derivation of the raster from contour data can also be problematic. I will discuss both later in this chapter. Unfortunately the majority of this area of Bodmin Moor has not been subject to the Environment Agency's programme of LiDAR survey. However, where it was available, data with a horizontal resolution of 1m and vertical resolution of 1cm were purchased.

The majority of the archaeological data layers were kindly supplied by the Cornwall & Scilly Historic Environment Record (HER) as a set of ESRI shapefiles. The HER data are collected from a number of different sources: fieldwork, surveys and excavations, published and unpublished books and pamphlets, specialist journals, antiquarian authors, museum records, and information sent in by members of the public. The HER webpage states, “the level of detail and the accuracy of the information held on each site reflects the nature or content of the sources used to compile the record. With over 56,000 records in the dataset it has been possible to verify the information 'on the ground' in only a small percentage of sites” (Cornwall Council 2013). Other archaeological features (including the location of some of the monuments) were digitised directly from information supplied in Johnson and Rose (1994) and Herring *et al.* (2002). The data in Johnson and Rose were collated from a survey of Bodmin Moor at scales of 1:2500 and 1:1000. Due to the use of these disparate datasets, it is important to realise that the spatial accuracy of some features, especially from the HER, may vary. However, the majority of the monument data within my study area were supplied to the HER as a direct result of the Johnson and Rose survey and therefore will be spatially accurate above scales of at least 1:2500. In terms of classificatory accuracy (such as the names of different types of monument), the HER data are mapped to the English Heritage INSCRIPTION thesaurus (English Heritage National Monuments Record 2013), which is the standard classification system used in HERs across the UK. The Johnson and Rose survey is also directly mapped to this thesaurus.

The data were collated within the QGIS (QGIS 2012) software program and any spatial adjustments (merging, clipping, reprojecting) were undertaken using the GDAL/OGR (GDAL 2012) tools. The more technical analyses (viewsheds, *etc.*) were undertaken within GRASS GIS (GRASS GIS 2012), the processing of which will be explained in further detail below. For further details of the software I have used throughout this thesis, please refer to Appendix Three. My choice of software was governed both by a commitment to the Open Source movement (Bonaccorsi & Rossi 2003) and also by the need for extending the software using scripting methods. In addition, the algorithms used within GRASS GIS are widely published and in comparison to some other closed-source GIS programs (such as ESRI's ArcGIS) they can easily be built upon and extended where necessary. As will become clear later in this chapter, some of my analysis required large repetitions of analyses and the capabilities of GRASS GIS to script and manage this proved invaluable.

Having introduced the data that I have collated for the GIS analyses, I will now discuss the various types of GIS analysis that I have undertaken, in order to address a number of the questions raised in the previous chapter.

A Viewshed Analysis of the Landscape

As explained in Part One, GIS analyses have moved beyond the criticisms of the early 1990s and are now increasingly attempting “to engage with human scales of landscape and with places as sociocultural and experiential phenomena” (Rennell 2012, p.513). One of the common methods used to approach this is visibility study or viewshed analysis (Wheatley & Gillings 2002, chap.10; Conolly & Lake 2006, p.225). As touched on in Chapter One, there are other 'sheds' used within archaeological investigation, such as soundsheds (Mlekuz 2004; Rennell 2009) and sensesheds (Frieman & Gillings 2007), some of which will be explored further in Chapter Eight.

Visibility analysis in landscape archaeology is well-represented within the archaeological literature (see Bender *et al.* 1997; Tilley 2004; Woolliscroft 2001 for just some examples). Fraser (1983), Bender *et al.* (1997, pp.156–166) and contemporary studies show that visibility is the principal way in which humans relate to and interpret their landscapes (Chapman 2006, p.84). Traditionally, manual visibility analysis is undertaken by visiting the site(s) in question and recording what can be seen from a certain point, or more likely in archaeology, what monuments can be seen from other monuments - their *intervisibility.* In GIS terms, viewsheds are essentially a computational calculation and representation of the regions of intervisiblity within a landscape.

The viewshed of a viewpoint is the set of target cells that can be seen *from* the viewpoint (see Conolly & Lake 2006, pp.225–233). There are a number of different types of viewshed that can be calculated, including *point-to-point* (a simple calculation determining whether one point can see another) which has been used for determining whether a person standing at one monument can see another monument (Woodman 2000); *point-to-areal* (how much of a specified area can be seen from a specific point) which was used by Fisher *et al.* (1997) to investigate whether cairns on the Isle of Mull were deliberately placed to overlook the sea; *cumulative viewshed* (the total area that can be seen from a number of different points) used by Wheatley to study the intervisibility of long barrows in southern England (Wheatley 1995); and a *total viewshed* (a raster map showing the amount of the entire landscape that can be seen, essentially a cumulative viewshed calculated for every point in the landscape), used by Llobera to study the prominence of monuments in the landscape (Llobera 2001; Llobera 2003).

The criticisms of viewshed analysis have been well rehearsed and discussed by Chapman (2006, pp.101–103), Conolly and Lake (2006, pp.228–233), Wheatley and Gillings (2000; 2002, pp.209–216). Conolly and Lake break these criticisms into convenient areas of concern, substantive issues (those that concern the initial choice of parameters and data); experimental issues (concerns that arise once the experiment is underway); and computational concerns (mainly related to the way various algorithms and analyses are programmed within specific software). There is no need to rehearse all of the problems here. However, I will discuss the concerns most pertinent to my study. Where appropriate, I will also raise the concerns as they relate to the Leskernick Hill case study and how I might go about addressing them.

Substantive issues. One of the major criticisms that applies to both traditional and computational visibility analysis is that of the palaeoenvironment and palaeovegetation (Wheatley & Gillings 2000, p.5). If one is standing on a modern hill undertaking manual visibility analysis or using a DEM that is based on the data taken from the modern landscape-form there is no guarantee that it will be a suitable model for the prehistoric landscape. Clearly vegetation also has a major effect on the visibility from a site – and this will even change throughout an individual year (when trees come into leaf, *etc.*). When dealing with Leskernick Hill and its surrounding landscape this is no less the case; however, as explained in Chapter Four, the available environmental evidence would seem to suggest that the landscape of Bronze Age Leskernick was dominated by grassland and heath, meaning that at least on the uplands, the vegetation was likely low-lying enough to have had a negligible effect on visibility. There is a suggestion that slightly larger trees were present in the lower river valleys of Bodmin Moor. However, this is likely to have been on the low-lying areas of the Moor and not the higher valleys surrounding Leskernick Hill (Tilley 1996, p.163).

Without a full geological survey of the Moor it is difficult to say exactly how different the form of the land itself would have been in the Late Neolithic or Bronze Age – the formation of the peat only began during the Late Bronze Age (Straker et al. 2007) which is likely to have raised the ground level in a number of areas. In addition there have been major intrusions during the post-mediaeval period in the form of tin-streaming channels, associated leats and other groundworks. These modern intrusions can be quite easily rectified by virtually 'filling' them, *i.e.* artificially raising the areas of known modern intrusions by changing the values in the DEM itself. The landscape change due to the build-up of peat is a little more problematic, as the peat is likely to have formed differently across different areas of the site. A normal solution to this would be to use geological borehole data to measure the level of peat across the site and then alter the DEM accordingly. This type of survey has not been undertaken on Leskernick, therefore we are left with the information retrieved from the limited excavation data. Using these data it would seem that the average thickness of the peat level in relation the the monuments themselves is only c. 0.3m (Bender et al. 2007, chap.4) and therefore, because of the vertical accuracy of the DEM (as mentioned above), this slight change is unlikely to adversely affect any results.

The problem of the contrast between the background and an object is another problem that applies to any visibility study of Leskernick. Contrast is a function of the innate properties of the target, atmospheric conditions and lighting (Felleman 1986 in Conolly & Lake 2006, p.231). Therefore, an object that has a high contrast to its surroundings may be visible over a greater distance then one that is similar to the background. For example, the houses of Bronze Age Leskernick were very likely to have been thatched with some form of grasses or reeds. Unless the ground surface was completely cleared of grassy ground-cover, the roof covering would not contrast very starkly with the ground itself, resulting in a slight camouflaging of the houses. As explained in Chapter Four, the stone circles and rows are not constructed of particularly high or impressive stones and would also presumably have not have contrasted particularly well with the surrounding landscape (this is certainly true today, as evidenced by Bender *et al.'s* use of flags to mark the stones). Of course, as with any use of the modern landscape and modern perception to investigate past perception, we cannot be sure if the contrast (or lack of) of the houses, the monuments, the clitter stream and the tors was in fact important to the people inhabiting the hill.

Reciprocity of view and the height of the observer are both factors that will feature in my analysis. As outlined in Conolly and Lake (2006, pp.229–230), when using offsets to distinguish between the target and the observer, for instance, an observer with a height of 1.7m looking at the actual ground surface, it does not necessarily follow that the view would be reciprocal for an observer standing at the target, attempting to view the ground at the original observer's feet. It follows that reciprocity is only a problem when attempting to test from site to landscape and landscape to site and comparing the results. As will be seen in my analysis, I am always calculating from site to landscape, and never vice versa, therefore reciprocity of view is not an issue in my case. The height of the observer is a slightly different matter and is one that is contentious even in manual visibility studies. For instance, the height of the house doorway chosen by the Stone Worlds team was 1.4m, chosen as it was the height of the smallest team member (Sue Hamilton), “and the closest we could come to an imagined Bronze Age person!” (Bender et al. 2007, p.51). The visibility analysis undertaken from the house doorways involved the team members ducking to look through the doorways, presumably further lessening the observer height. This is in contrast to the wider landscape visibility analysis of Bodmin Moor undertaken by Tilley (Tilley 1996; Tilley 2012) which, although not noted in his publications, was taken from his own eye-level (S. Hamilton, *pers. comm.*). Although I do not know Tilley's exact height, he is not a short man; therefore it could be presumed that he is at least six foot tall, suggesting an eye-level of approximately 1.7m. As Lock and Harris (1996) have shown in their computer-based visibility experiments at Danebury hillfort, the observer height has a marked effect on the resulting viewshed. As an illustration of this, Hamilton has stated that when she was undertaking fieldwork with Tilley, “things came into view for each of us at a different time” (S. Hamilton *pers. comm.*). A further issue is that once the observer height is set for a viewshed it cannot be changed, and therefore needs to be carefully chosen in order to represent the range of heights that presumably existed amongst the people of Leskernick. To avoid the accusation of underplaying the diversity of human experience (Brück 2005, p.59), one which is frequently addressed to the white Western male phenomenologists striding through the landscape (Hamilton et al. 2006, p.35) it is vital to allow for this range of diversity. This can be achieved by creating a range of viewsheds using different observer heights and then creating a probabilistic map showing the likelihood that a person of unknown height would be able to see the target.

Experimental issues. The 'edge effect' is a limiting factor in visibility analysis, particularly when comparing the size or shape of different viewsheds across a landscape. The edge effect comes into play when the DEM data are not sufficient to cover the whole of the maximum viewing area of the viewshed, leading to an artificial truncation (and hence smaller size) of the resulting viewshed (Conolly & Lake 2006, p.229). This can normally be solved by performing the viewshed analysis on a region of a DEM which is surrounded by a buffer zone. However, as I do not compare entire viewshed sizes in my visibility analysis and all my point-to-areal calculations fall within my 10km study area, the edge effect is negligible.

The quality, accuracy and resolution of the underlying DEM itself clearly has an impact on any GIS-based viewshed analysis. As noted previously, the main DEM data used were the Ordnance Survey's Landform PROFILE dataset which has a 10m horizontal resolution. This DEM is interpolated from contour lines and therefore is susceptible to the 'terracing' caused by the lack of data to interpolate from inbetween the contour lines and a clustering of data values around the contour lines themselves (see Conolly & Lake 2006, pp.103–106). This phenomenon is usually more evident in the flatter areas of the landscape (Ordnance Survey 2001, p.14). However, as can be seen from a slope map derived from the DEM (Figure 33), the characteristic 'tiger-striping' resulting from the underlying interpolation errors (Conolly & Lake 2006, p.105) is quite prominent in some areas. As viewshed algorithms are sensitive to sudden changes in height, these false peaks of the tiger-striping are likely to have an adverse effect on the resulting viewsheds. The problem can be in some way mitigated by 'smoothing' the DEM (using a low-pass filter – see Conolly and Lake [2006, pp.200–201]). By its very nature, smoothing levels out the elevation and directly changes the maximum and minimum values of the DEM. In some cases this can be detrimental to the analysis as the extreme high and low areas of a landscape can potentially be important (Fisher 1993). With this in mind, I chose not to smooth my DEM. Another way to avoid tiger-striping is to use elevation data entirely derived from spot heights (such as LiDAR). However, as the LiDAR data were not available for the whole of the study area and it was entirely impractical to undertake my own topographic survey, the PROFILE data were the best quality available and therefore taken forward to my visibility analysis.

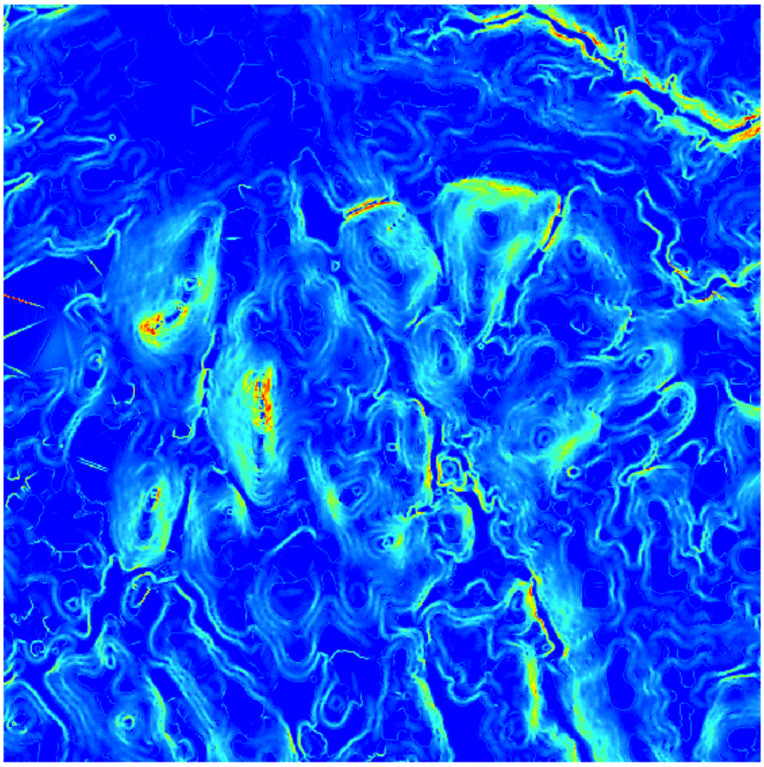


Figure 33 - The slope map derived from the base DEM. As can be seen there is clear evidence of 'tiger-striping' resulting from the previous interpolation from contour lines.

Computational issues. One of the major computational concerns is the quality of the algorithm used to undertake the viewshed analysis itself. A study of viewshed algorithms shows that the algorithms employed by different software packages can have a large effect on the resulting viewshed and create different results even from the same input data (Fisher 1991). For my analysis I have chosen to use the r.viewshed package within the GRASS GIS software suite (Haverkort et al. 2009). I explained the reasons for my choice of GRASS GIS previously (it is open-source software and easy to script), and these reasons, coupled with the computing effectiveness of the r.viewshed implementation, were instrumental in choosing this method. As far as I am aware there have been no recent direct comparisons of the accuracy of any of available algorithms on the ground (see Maloy & Dean 2001; Kaučič & Zalik 2002 for comparisons using older software), therefore throughout my analysis I was continually comparing the results with the actual results on the ground. As will be seen in Chapter Seven, by using the embodied GIS, this ground-truthing can be carried out *in situ*.

A further issue, raised by Wheatley and Gillings (2002, p.209), is to do with the interpretation of the viewshed results themselves. Frequently, even if a pattern is shown between the visibility or intervisibility of a monument it does not necessarily follow that visibility was the sole reason it was constructed in that specific location. For example, it may be that the monument was placed on higher ground because it was drier, or because a specific difficult journey had to be undertaken to reach it - however, higher ground tends to have a larger viewshed and therefore there would be a spurious correlation (Shennan 1997, pp.121–125). Care must be taken when inferring human behaviour from any visibility results, as we may be witnessing correlation, not necessarily causation (Figure 34). This is especially true when dealing with multiple scales of analysis. Throughout my analysis I will examine the settlements on Leskernick Hill on a macro-scale (what brought the people to Leskernick in the first place?) and a micro-scale (why did they place their houses in those exact positions?). The patterns I present during these analyses will be relevant to the scale I am looking at and they may have different and external causes, but they will still be correlated to the patterns displayed at the other scales (see Fisher et al. 1997; Lake & Woodman 2003 for archaeological examples of this).

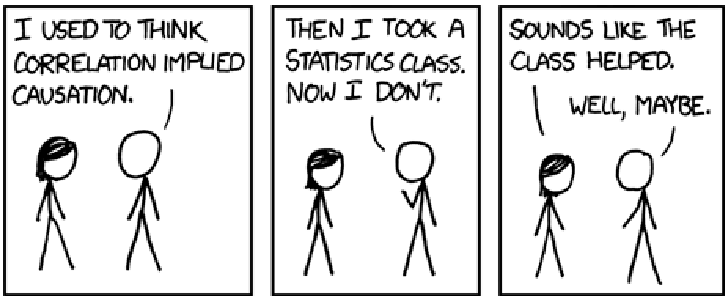


Figure 34 - http://xkcd.com/552/

Computational viewshed analysis has been used in many archaeological studies. Van Leusen (1993), Gaffney and Van Leusen (1995) and Wheatley (1995) provide early examples, exploring the potential of the technique. Responses to the challenges (outlined above) were developed within visibility analysis studies such as those by Woodman (2000) who developed methods for dealing with the reciprocity problem; Fisher *et al.* (1997) who used spatial statistics and Monte Carlo simulation to create probabilistic viewsheds; Lake *et al.* (1998) who rewrote a number of common GIS algorithms to increase the efficiency of the analysis; Llobera (2001; 2003) who developed the total viewshed as the next logical step up from a cumulative viewshed; and Gillings (Frieman & Gillings 2007; Gillings 2012) who is exploring senses beyond just vision. However, as asserted by Lake and Ortega (2013), the subsequent relative paucity of visibility analysis in the past ten years may be assigned to the lack of the increasingly significant computing resources needed to handle the responses to the criticisms outlined above (generating multiple probabilistic viewsheds, algorithm inefficiencies, quality of available data, *etc.*).

Computer-based Visibility Analysis of Leskernick Hill

Now that I have outlined the basis of visibility analysis and introduced some of the advantages and disadvantages of the approach I will present my use of visibility analysis on Leskernick Hill. I begin by undertaking some ground-truthing of the methodology, by comparing the initial computed results to the *in situ* results published by Tilley *et al*. As touched on previously, the scale of analysis is very important, therefore, in order to explore the reasons for house placement and also to elucidate further on the individual experience of the settlers of Leskernick Hill (see Chapter Four), I begin at the micro-level. Ignoring initially the question of the wider pattern of settlement over Bodmin Moor (*i.e.* why the settlements were put on the southern side of Leskernick Hill in the first place), I investigate whether the houses themselves have been micro-placed in the settlements to command views of specific areas of the landscape.

By using Monte Carlo simulation and cumulative viewshed analysis I will demonstrate the areas of the landscape that were likely to have been visible only if the location of the houses themselves had been carefully chosen. I have developed a new method for displaying the results of these calculations, a 'spatial confidence' map, and by using these maps it is possible to easily visualise the results and draw conclusions from them. By using the same method for the southern and western settlements individually, I draw conclusions about the possible reasons for their placement on the Hill. Following this examination of the micro-placement of the houses, I adjust the scale of the analysis slightly and look at the macro-placement of the settlements, particularly in relation to the mineral resources and ritual monuments of the surrounding area. By developing a new variation of the viewshed, the 'visibility field', it is possible to show areas of the landscape that afford certain views and can imply the areas that may have been more attractive for settlement (*c.f.* Gillings 2009).

Were the houses on Leskernick Hill specifically placed to afford certain views?

As I outlined in Chapter Four, it has been posited that the houses on Leskernick Hill were deliberately placed to take advantage of certain views of the various landscape features (natural and cultural) (Bender et al. 1997; 2007; Tilley 2012). The evidence observed on the ground would appear to support this argument, as Bender *et al.* show (2007, chap.4), the views to the hills of Roughtor and Brown Willy seem to have had a special significance to the inhabitants. However, Leskernick Hill is situated in a 'bowl' of hills, and Roughtor and Brown Willy are some of the highest peaks in Cornwall, so there is potential that these views would be recreated no matter where the houses were placed on the Hill. The only way to test whether or not this were true solely using fieldwork would involve manually recording the views from a large number of random positions on on the Hill. Clearly, this would take an inordinately long amount of time and effort to achieve manually, and therefore, it is an appropriate problem to tackle using GIS. Due to the increasing speed and efficiency of modern computer processors it is now possible to run quite complex computing routines on a relatively affordable system (see Lake & Ortega 2013). This opens up a number of possibilities for statistically testing hypotheses, especially hypotheses such as this that would normally require the creation of a large number of manual or computed viewsheds.

As previously discussed, I begin this analysis on the micro-scale. At this stage I am assuming that the settlement areas themselves were chosen for some other external reason(s) and therefore, rather than searching for a reason why the settlement itself is where it is on the Hill, I am currently only interested in the micro-position of the houses within the general settlement area. By limiting the investigation to the boundary of the settlement area, the other properties of the house locations will remain relatively constant, and therefore the likelihood of erroneously inferring some other type of causation will be reduced.

In order to investigate whether or not the houses were specifically placed within the settlement area to afford views of Roughtor or Brown Willy, I undertook a number of experiments using a Monte Carlo approach to a series of viewsheds (building on the work of Fisher et al. 1997; Lake & Woodman 2003). Monte Carlo methods are those in which properties of the distributions of random variables are investigated by use of simulated random numbers (Kotz et al. 1998). By comparing an actual pattern with a series of random patterns, the statistical probability that the actual pattern is different from the expected pattern (if it were a purely random pattern) can be calculated. In this case I have the actual locations of the houses on Leskernick Hill, and a polygon of the settlement area in which the houses are contained (Figure 35). First, I adopt a null hypothesis that the houses within the settlement area are *not* placed to command views of particular areas of the landscape. I then create a cumulative viewshed from the actual locations of the fifty houses, by creating an individual viewshed for each house and then summing all of the individual viewsheds together (see the discussion of viewshed types above). Fifty random points, constrained by the settlement area, are then placed, and produce the cumulative viewshed of the random houses. By comparing the cumulative viewshed of the actual locations of the houses with a series of cumulative viewsheds created from random patterns of house placements it is possible to calculate which are the areas of the actual viewshed where we can reject the null hypothesis, thereby inferring which areas of the landscape are unlikely to have been visible if the micro-placement of the houses were entirely random.

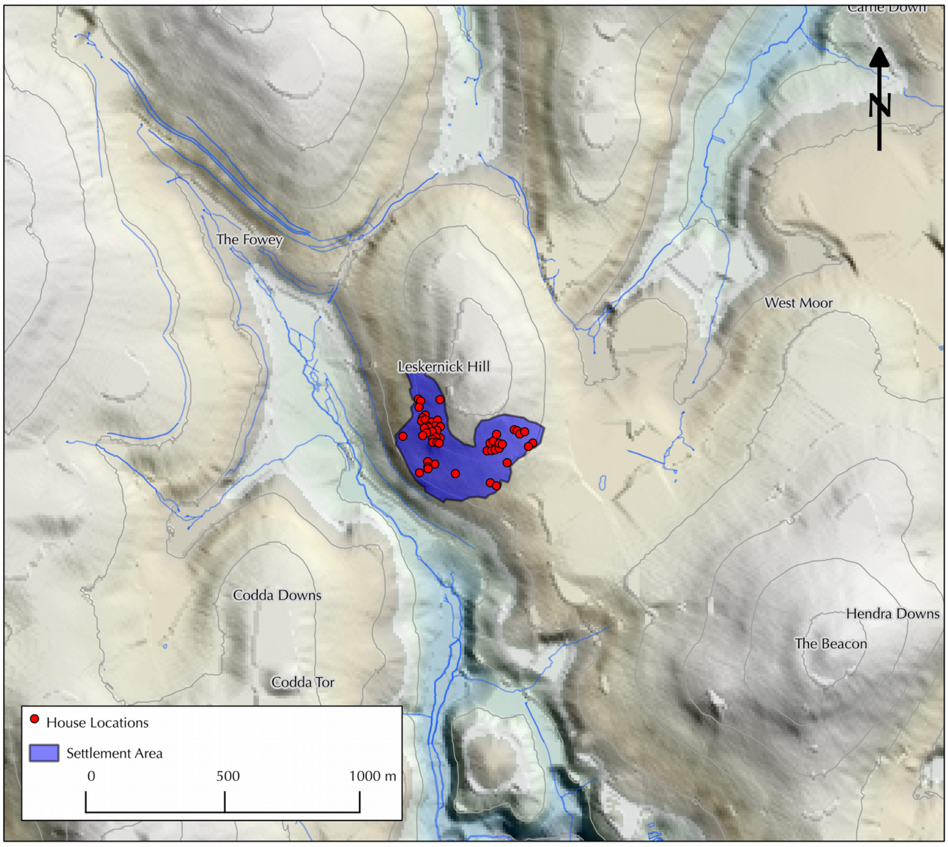


Figure 35 - Houses and Settlement Area

The process is as follows:

1. Calculate the cumulative viewshed of the known locations of the houses (a total of fifty individual viewsheds, one for each house).
2. Randomly create fifty point locations (to match the number of houses), constrained by the polygon of the settlement area.
3. Calculate the cumulative viewshed of the random point locations.
4. Repeat points 2 and 3 forty-eight further times (the reason for running this process a total of forty-nine times is explained below).

Once the forty-nine random cumulative viewsheds are calculated, they are compared in turn to the cumulative viewshed from the actual house locations, and the test statistic is calculated. Each of the cells in the cumulative viewshed raster maps are coded with the number of houses that can see that cell. Therefore, a value of fifty means that the cell can be seen from every house in the settlement, and a value of zero means that the cell cannot be seen by any of the houses (Figure 36 and Figure 37).

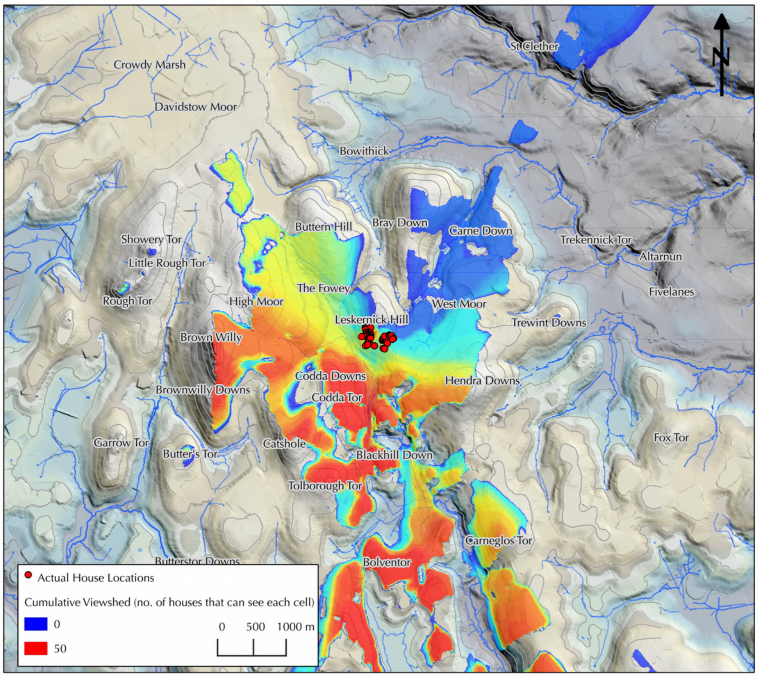


Figure 36 - Results of the cumulative viewshed analysis of the actual house locations

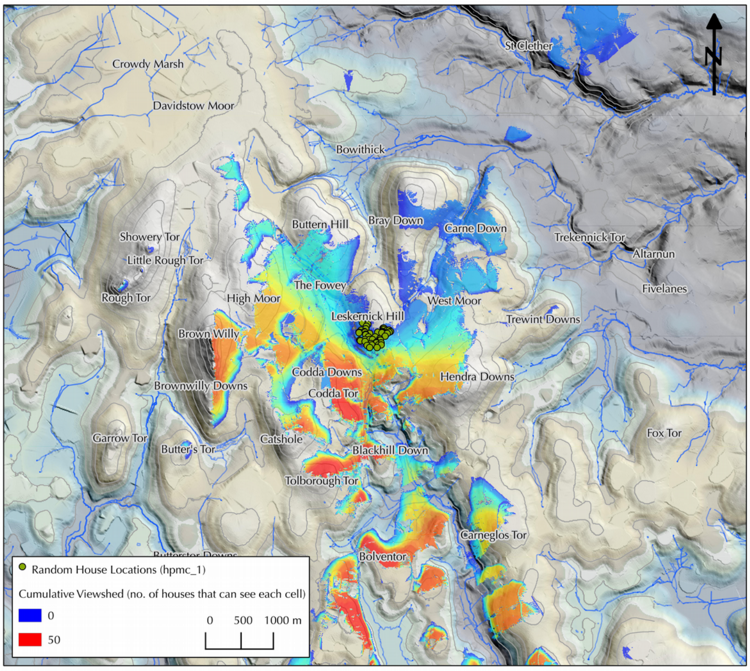


Figure 37 - Results of the cumulative viewshed analysis of a set of random house locations

When comparing the actual cumulative viewshed with the set of forty-nine random cumulative viewsheds, the values are ranked and the position within the ranking governs whether or not the actual value is statistically significant when compared with the random values. By adding the forty-nine random cumulative viewshed runs to the actual house location run, we have the equivalent of fifty runs, therefore it is possible to calculate to a confidence value (*p-value*) of 0.05. This means that if the actual value is ranked lower than the random values, we can be 95% confident that the number of houses that can see that cell would not have occurred by chance alone (see Fisher et al. 1997; Conolly & Lake 2006 for further explanation of this technique).

Whilst Monte Carlo simulation is being used increasingly frequently within archaeological studies (Fisher et al. 1997; Lake & Woodman 2003; Crema et al. 2010; Crema 2012; Lake & Ortega 2013), when using geographic data it is often difficult to visualise the results. The usual method of displaying the results of a Monte Carlo simulation would be to plot a Empirical Cumulative Distribution Function chart showing the actual value(s) alongside an 'envelope' of the random values (Wilk & Gnanadesikan 1968). If the actual values fall within the envelope then the pattern being observed is not out of the ordinary.

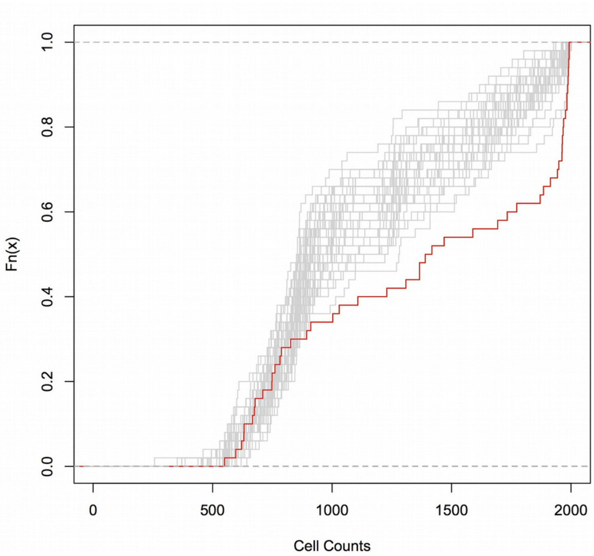


Figure 38 - An example of an ECDF plot, showing the results of a Monte Carlo simulation. The observed pattern is shown in red, if it is outside the grey envelope it suggests the pattern is out of the ordinary.

However, by following the process as outlined above I am calculating the *p-value* for every cell within the raster. In the case of my dataset using a 10km x 10km raster with 10m horizontal resolution, this results in 1,000,000 Monte Carlo plots (one for each raster cell). This is clearly not feasible for reproduction in this thesis and also would be virtually unusable. Therefore another, more innovative, approach was needed in order to visualise the results.

Before introducing the new visualisation method, it is worth explaining what this process means in real terms on the ground, and how this helps to address my original question regarding the views to Brown Willy and Roughtor. Firstly I am calculating how many houses in the settlement would have visual contact with a specific cell which represents a real 10m x 10m square on the ground in the actual landscape. This is the equivalent of me visiting every one of the fifty houses in the settlement and recording the exact parts of the landscape that I can see from them. This is not perhaps such an onerous task to undertake, however, I am then effectively visiting fifty random places in the settlement area and doing the same thing. Then I am repeating this process a further forty-eight times. It quickly becomes an unwieldy and impossible prospect to undertake manually, and something that is better delegated to a computer. The reason for the repetitions is to ensure I have a suitable random sample to compare my actual results to. By using the Monte Carlo method I am able to calculate the probability that the number of actual houses that can view a specific area of the landscape would not have happened by chance alone. In simple terms, if the specific cell has a high *p-value* (closer to 1.0) it is likely that wherever the houses had been placed within the settlement area they would have been able to see that cell. It follows, then, if the cells containing Brown Willy or Roughtor have high *p-values* (meaning the red line on their specific ECDF plots is within the grey envelope), it is likely that they would have been visible from the houses no matter where in the settlement area they were placed. This would suggest that the houses were not deliberately placed within the general settlement area to afford preferential views of the Brown Willy or Roughtor.

Spatial Confidence Mapping

As I stated above, it is possible to calculate the *p-value* of every cell in the raster, but it is unfeasible to present the results for each cell as an ECDF plot. As I am dealing exclusively with spatial data, it made sense to instead find a way to view these results spatially within the GIS. Therefore I devised a way to use the raster map calculator functionality of GRASS GIS to undertake the calculation for each cell and display it on a map. I refer to this method as Spatial Confidence Mapping. This was undertaken using a Python script, an excerpt of which is provided below:

```
SC = 0
 for i = 1 to N {
       if (HCV <= RCV) {
              SC = SC + 1
       }
 }
SC = (SC + 1) / (N + 1)
```

Snippet 1 - SC = Spatial Confidence Map, N = number of random runs, HCV = House Cumulative Value (actual house locations) and RCV = Random Cumulative Value (the value from the random run).

This script creates a new raster map, the Spatial Confidence (SC) Map, which is a result of a nested loop that calculates the *p-value* for each individual cell by comparing the results of the actual house's cumulative viewshed with the results from every one of the random runs. The final line in the code then converts these values into a *p-value*. Therefore, as there are forty-nine random runs (N) if the SC map has a value of forty-nine, the *p-value* is calculated by `(49 + 1)/(49 + 1)`, which equals one (i.e. it is highly likely that the cell would be visible by chance alone). Alternatively a SC value of zero (`(0+1)/(49 + 1)`) results in a *p-value* of 0.02, suggesting a very high probability (we can be 98% confident) that the number of actual houses that can see that cell would not have happened by chance alone. The net result of this is a map that shows the areas of the landscape that are unlikely to have been seen unless the houses were specifically placed within the entire settlement (*p-values* of less than 0.05), and those areas that were likely to have been seen no matter where in the settlement the houses were placed.

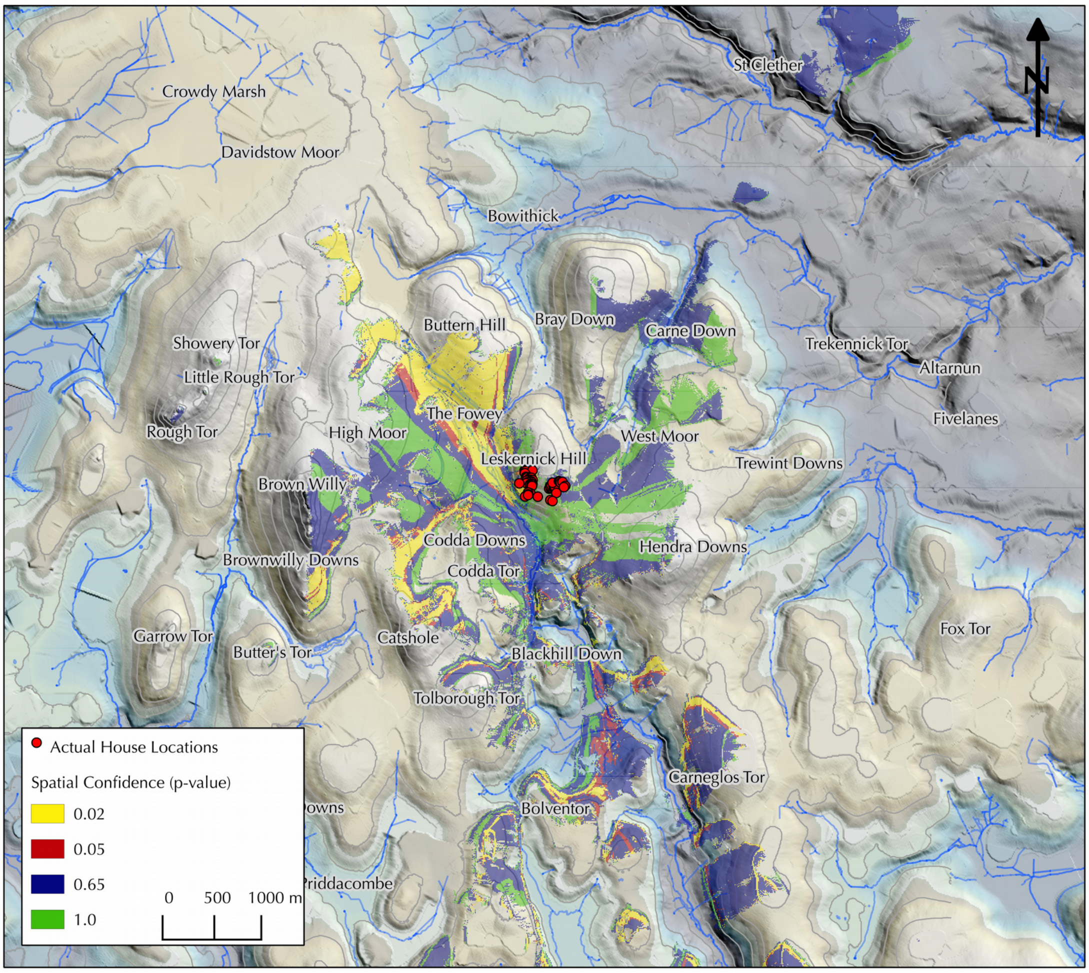


Figure 39 - Spatial Confidence map for the entire settlement

Once the Spatial Confidence map is plotted (Figure 39), it is possible to see the areas of the landscape that would not normally have been visible without deliberate micro-placement of the houses (*e.g.* with a *p-value* of 0.05 or less). Contrary to Bender, Hamilton and Tilley's suggestions, at least when looking at the settlement as a whole and not taking into account hut doorway orientation, it would appear that the cairns, the tip of Roughtor, the stone circles and the stone row are quite likely to have been visible no matter where the houses were placed within the settlement area. Whilst this does not mean the views were not important or culturally meaningful, it does show that it is difficult to prove they *were* simply on the basis of intervisibility. My analysis suggests that the houses were *not* placed in specific places within the settlement area solely to command views of the natural and cultural features. It should be reiterated that this analysis is only concerned with the placement of the houses at a micro-level – it could be argued that the reason the settlement area itself was chosen was to afford a good *overall view* of the features on the macro-scale.

The SC map also reveals a number of areas that may not have been previously considered as 'significant'. The most important of these is the Fowey river valley, on the western part of the site: as can be seen from Figure 40, the majority of this valley and the south-western slopes of Buttern Hill (itself topped with five different cairns) have a *p-value* of 0.02, suggesting very strongly that the houses were placed in order to have a good view of this section of the Fowey valley, or at the very least, that the houses would not have such a view of the expanse of the valley bottom if they were randomly placed within the confines of the overall settlement area.

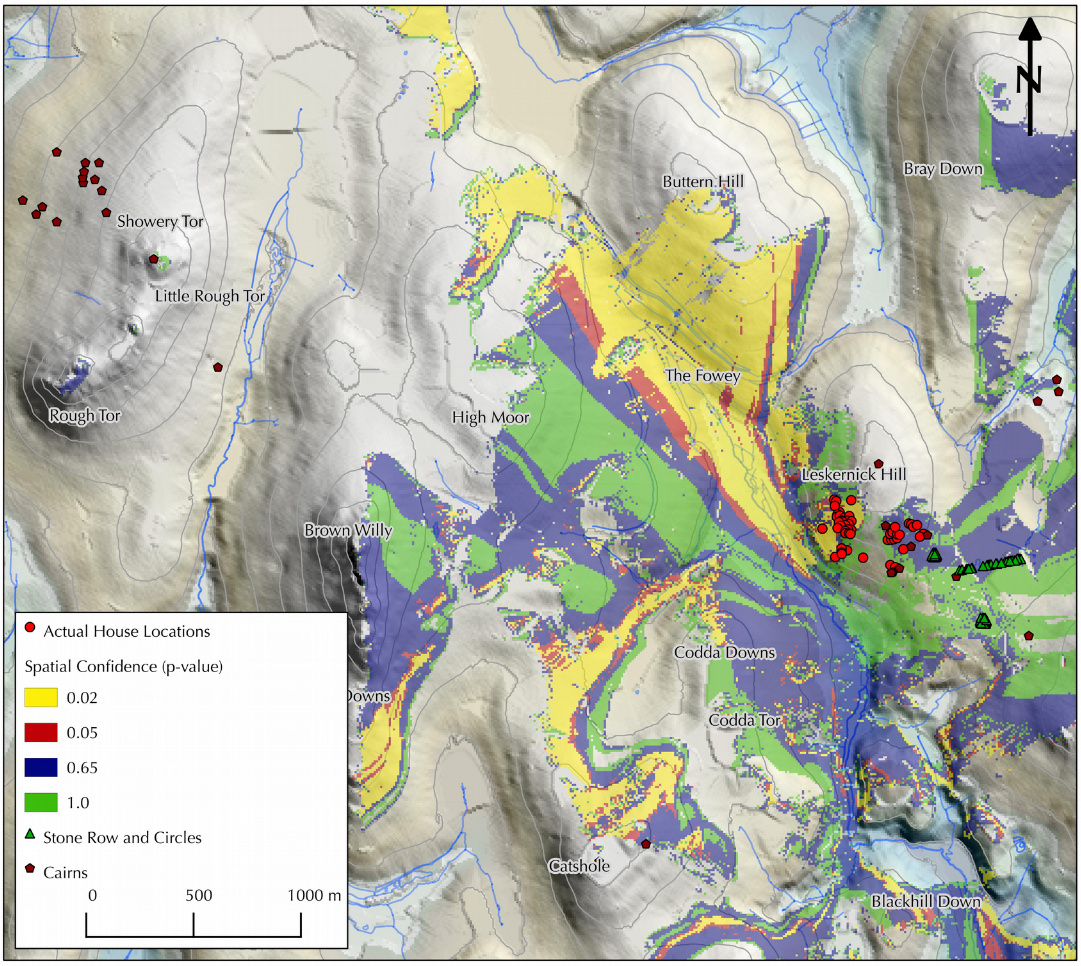


Figure 40 - Spatial Confidence map for the entire settlement showing archaeological features

A number of reasons for this preferential view can be posited. As it is a valley bottom, the area is quite marshy, and therefore it may concur with the commonly held belief that watery places and marshes were important during the Bronze Age (Bradley 2000; Pryor 2004; although see Pendleton 2001 for a challenge to this belief). Additionally, this particular part of the valley has been intensively exploited during the post-mediaeval period for eluvial tin (see Chapter Four and also my discussion below) and therefore we can suggest that if the area were also being exploited in the Bronze Age, that the houses were placed to enable easy access to and visual monitoring of the tin-working area. This follows the pattern shown by Bauer (2011) in which Iron Age Indian iron-workers and shepherds placed their houses to have better monitoring of the grazing and metal-working areas. The final, and wholly functionalist, suggestion is that this area was the closest area with a suitable water supply – and therefore was where most village activities took place (watering animals, collecting drinking water, harvesting reeds, *etc.*). The use of this area is in some way corroborated by the "funnel-shaped entrance" (Bender et al. 2007, p.154) that leads out of the western settlement down to the river. As Bender *et al.* suggest "…it requires little imagination to see people walking down to the spring to fill their containers, taking their animals down to the river, setting out on expeditions to cut rushes, catch fish, trap animals, gather plant foods along the river banks, or trudging home with bundles of firewood" (2007, p.154). It is possible that if this area was indeed where all these activities were taking place, that the houses would have been placed to have a good view to (and from) the river.

I will explore the implications of this analysis from a macro-scale perspective later in this chapter. However, before I change the scale, it is worth examining what else the analysis can show about the micro-positioning of the houses, this time looking at each settlement individually. As explained previously, the Stone Worlds team divided the settlement into two distinct areas, the southern and the western settlement (Figure 41).

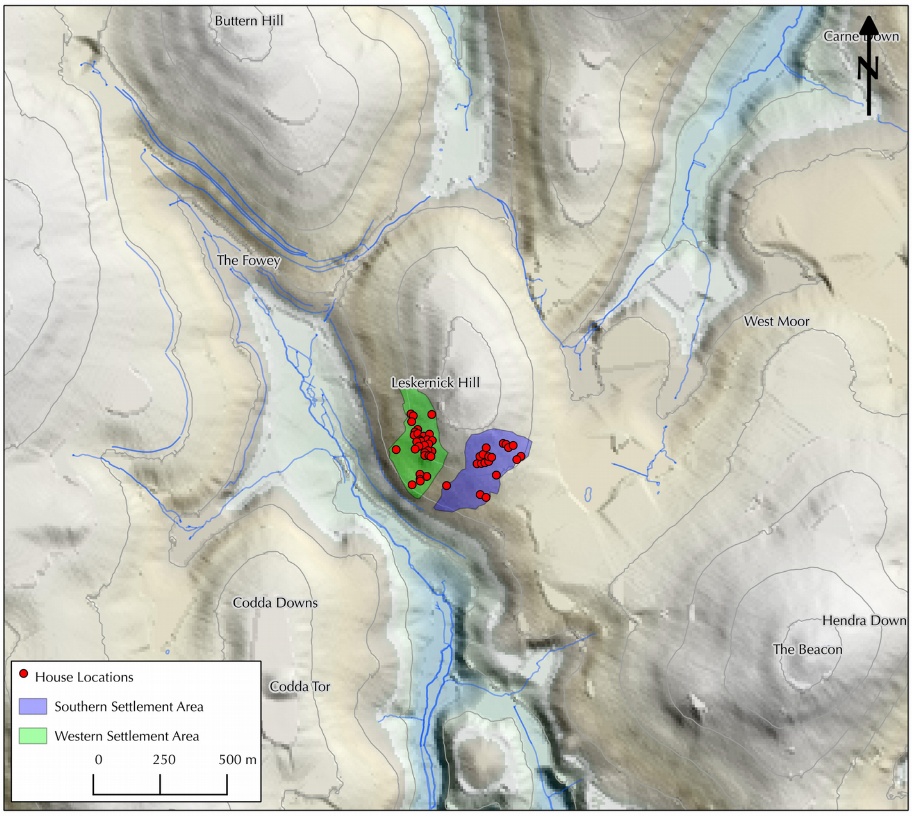


Figure 41 - The Southern and Western Settlement Areas

It is not clear if these two settlement areas were developed at the same time: the Stone Worlds team suggest (mainly due to the limited radiocarbon dates) that the southern settlement area was settled a little before the western area. When a Spatial Confidence map is created only for the nineteen houses of the southern settlement, a different pattern emerges.

The Southern Settlement

As can be seen from Figure 42, the spatial confidence map does not show any major areas in the wider landscape that are unexpectedly visible because of any micro-placement of the houses in the southern settlement area.

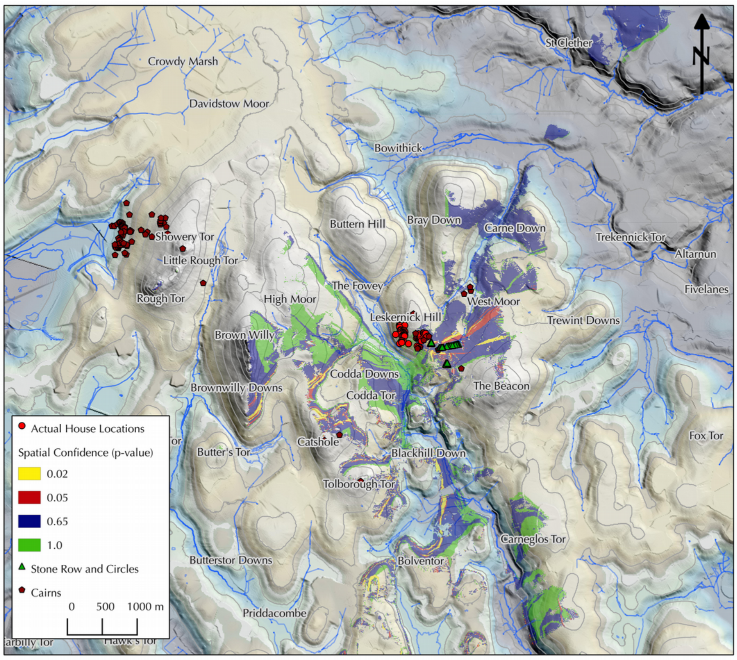


Figure 42 - Spatial confidence map for the southern settlement

Herring (1997) suggests that the earliest of the houses of the southern settlement were placed to take advantage of and respect the earlier ceremonial monuments. If this is the case then the spatial confidence map should show that the view of the monuments from the houses is statistically significant rather than just a matter of chance.

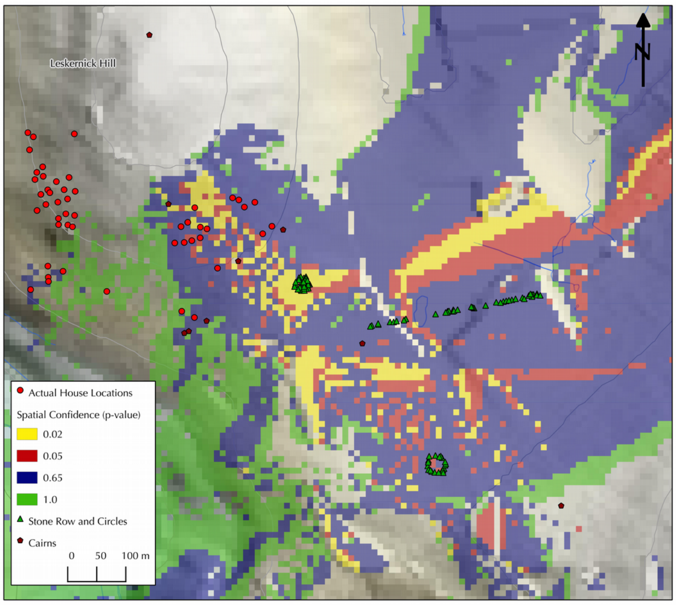


Figure 43 - Spatial confidence map for the southern settlement, showing the ritual area

When the ritual area is looked at more closely (Figure 43), it would seem that this pattern is indeed present. The SC map shows that no matter where the houses were placed within the southern settlement area, views of the stone row and the southern stone circle would have been present. However, the northern stone circle is situated directly in the centre of an area of unexpected visibility (a *p-value* of 0.02). This is an intriguing result, as contrary to the belief that the three ritual monuments (the stone row and both stone circles) are all broadly contemporary and were revered in the same measure, the houses would appear to have been located carefully to command a view of the northern stone circle alone, which would not otherwise be so apparent had they placed their houses elsewhere on the southern side of Leskernick. This, of course, does not mean that the stone row and the southern circle were any less important to the people inhabiting the southern settlement, as the high *p-value* shows that the general location of the southern settlement area commands excellent views of the monuments, but it may suggest a different nature of or attitude towards the northern stone circle.

The exact sequence of construction between the earliest houses of the southern settlement and the northern stone circle is uncertain. The radiocarbon date of the northern stone circle (1750-1540 cal BC) places it slightly earlier than the earliest date from the southern settlement (House 39, 1525-1375 cal BC) (Bender et al. 2007, Table 4.1). These would seem to suggest that the houses were built after the construction of the northern stone circle. However, only a limited number of the houses in the settlement have been radiocarbon dated, therefore some of the other houses may have earlier construction dates than House 39. There may also be a case for suggesting that the northern circle was constructed *after* the first houses were erected. Excavations undertaken of the circle showed that the monolith at the centre was originally an earth-fast boulder and, rather than being stood upright, it was instead levered out of position and then skewed round (Bender et al. 2007, pp.103–105). The radiocarbon date for the stone circle was taken from beneath this stone and there are no dates for the erection of the surrounding stones. The stone circle's unusual visibility may suggest that it was reserved for use by the inhabitants of the southern settlement, almost a private circle, the visibility of which was carefully controlled and curated by the inhabitants of the houses on that side of the hill (Herring 1997). However, it is not clear if the houses were erected deliberately in that position to command a view of the initial stone-fast boulder or if the stone circle itself was erected in that location precisely so it could be seen by the houses. Perhaps the stones that make up the circle were erected at a slightly later date, to serve as a ritual area for the southern settlement, in this very specific area of reserved visibility.

The Western Settlement

As can be seen from Figure 44, the spatial confidence map of the western settlement demonstrates that the upper part of the Fowey valley would be visible no matter where in the western settlement area the houses were located. When coupled with the results of the entire settlement (Figure 41) this would suggest that the western settlement was specifically placed to take advantage of views of the upper part of the Fowey valley. This pattern is likely to be connected with the wider-scale choice of the actual settlement location, rather than just with the micro-placement of the houses within it. I will investigate this macro-pattern later in this chapter. The spatial confidence analysis also demonstrates, however, that the micro-placement of the houses within the settlement area provides an unusual view of the southern part of the Fowey valley, where the view opens out along the valley bottom towards Bolventor. Again, this could be to enable a view of the watery places, or the areas where animals were taken or firewood and rushes were collected, *etc.* This part of the valley bottom was also subject to tin-working in the post-mediaeval period, and when considered alongside the preferential views of the tin-streaming areas in the upper part of the Fowey valley, it raises the possibility that the western part of the settlement was deliberately placed to enable good visibility of the tin-working areas. In order to investigate this further it is necessary to undertake some further GIS analysis.

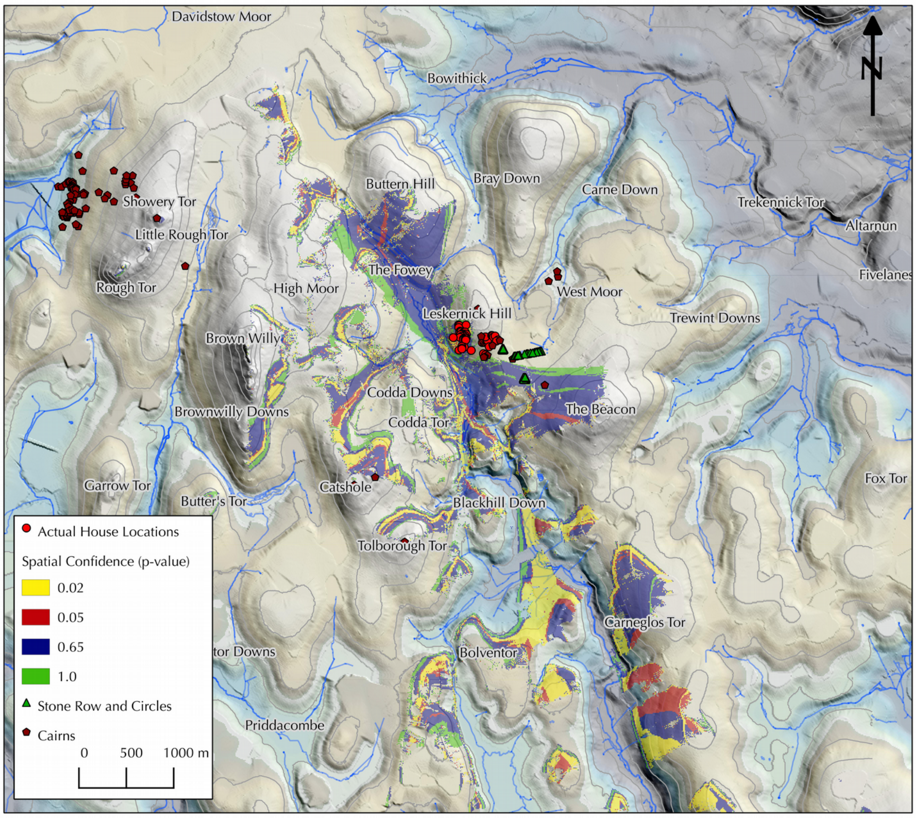


Figure 44 - Spatial Confidence map of the Western Settlement

Tin Working on Bodmin Moor

The importance of the tin-working industry of Bodmin Moor was briefly discussed in Chapter Four, in which I suggested the minerals of the Moor were of importance to the wider regional context of the Bronze Age in Britain. Before presenting the results of my further GIS analyses, I will expand on this situation in order to place my findings in context. It is a commonly held belief that Cornwall was the source of a large amount of the tin used throughout the European Bronze Age (Penhallurick 1986). Although there were other sources for tin in the ancient world (Iberia, Serbia and Erzgebirge on the German/Czech Republic border), Cornwall was for the most part the largest producer in Europe, and indeed remained so until the Malaysian and Australian tin industries took over in the 19th century (Penhallurick 1986, p.148). The implications of this claim are wide-ranging, as only approximately 12% of tin is needed to be added to 88% copper to make bronze (Knapp 1996). In his discussion of copper mines in the Bronze Age, Timberlake makes the clear distinction between the political or economic importance of the copper (the sources being very numerous) in relation to the tin and gold which were so much rarer and therefore may have been regarded with more importance (Timberlake 2001).

“Up to the 17th century most of Cornwall's output was from tin streams” (Penhallurick 1986, p.148). It is important to remember that tin-streaming is not the same as 'gold-panning'. The 'streaming' aspect comes from cleaning and streaming the ore in water once it has been dug up and crushed. Tin extraction is in fact a form of open-cast mining. It is necessary to dig down to the level of the tin ground to then extract the tin itself. The tin ground is always at the same depth, meaning the prehistoric tinners were extracting tin from the same tin ground as the mediaeval and post-mediaeval tinners. Therefore, a large amount of the evidence for Bronze Age tin extraction comes from the discovery of Bronze Age artefacts found on the tin ground during later tin extraction. John Leland, writing during his tour of Cornwall between 1534-1543 makes this clear: “there was found of late Yeres sysn Spere Heddes, Axis for Warre, and Swerdes of Coper wrappid up in lynid scant perishid, nere the Mount in S. Hilaries Paroch in Tynne Works” (Chope 1918, p.27). These refined artefacts were deposited wrapped in linen, suggesting they were deliberately placed on the tin ground. The majority of the earliest material found from tin stream-works (on the tin ground) in Cornwall comes from the Middle Bronze Age, with the exception of a jet slider from Pentewan Valley and a flat axe and two antler picks from the Carnon Valley dated to the Early Bronze Age (Penhallurick 1986, pp.219–221).

There is very little direct evidence for prehistoric tin-working on the site of Leskernick Hill. The closest evidence is a stone hammer, possibly used for grinding ore, from one of the cairns on Buttern Hill (Cornwall Historic Environment Record Number 3506.70), and a Bronze Age spearhead found in the tin-workings below the Jamaica Inn at Bolventor (Penhallurick 1986, p.207). During excavations on the settlement itself, circumstantial evidence of quartz chips were discovered, which may be a “by-product of the damage sustained by quartz pounders when used to smash something hard such as cassiterite [tinstone]” (Bender et al. 2007, p.122). The Stone Worlds team state that “..it seems highly likely that the exploitation of tin did occur at Leskernick" (Bender *et al.* 2007, p.170, and see pg. 442 [note 7.5]). However, probably due to the lack of direct archaeological evidence, they did not investigate this any further.

The lack of direct evidence for tinning could be the result of a number of factors. First, the excavations undertaken at Leskernick were relatively limited (a few houses and the ritual monuments), therefore evidence might not have survived in the specific areas of excavation, but that is not to say that it is not present beneath any of the other houses or in the communal areas. Second, as explained above, the majority of Bronze Age artefacts relating to tin working are found on the tin grounds themselves. Most of the tin ground in this area was exploited during the late mediaeval and post-mediaeval period, and if Bronze Age (or indeed later) artefacts were recovered, they were quite often taken as souvenirs by the tinners, or even thrown into the smelt along with the other recovered tin, "the discovery of ancient ingots of tin was just a bonus to many tinners who sweated long hours for little return" (Penhallurick 1986, p.173). This means that presumably much of the evidence was never reported and the artefacts were lost. The spearhead from Bolventor (only thirty minutes walk from Leskernick Hill) is certainly evidence that the Bronze Age inhabitants reached the tin ground nearby. However, the third possibility still remains that the people of Leskernick Hill were indeed ignorant of the mineral resource beneath their feet and Leskernick was simply an agricultural/pastoral settlement.

However, as discussed in Chapter Four, the settlement densities of Bodmin Moor and Dartmoor and the Wessex-style burial at Rillaton suggest a source of wealth beyond that of a simple pastoralism or cultivation economy. The inhabitants of Leskernick Hill were living on one of the major sources of tin in the ancient world, and yet there is very little direct evidence for them extracting it. It is possible, however, that the inhabitants of Leskernick settled on the spot precisely *because* the tin was there. However, this does not explain the presence of the earlier ritual monuments; indeed "...no good correlation has yet been made between Bronze Age mines and the distribution of Bronze Age monuments ... mid-Wales, which has the greatest number of potential mining sites, has a rather moderate distribution of Bronze Age monuments" (Timberlake 2001, pp.189–

190). The possibility does still remain, however, that they too were placed in an area rich in shode, a slightly glittering tinstone that would have been lying on the ground surface indicating the presence of the buried tin lodes (see Penhallurick 1986, p.76 for further explanation of shode tin). Perhaps the inhabitants settled without any knowledge of the tin deposits, and instead, as suggested by the Stone Worlds team, they settled because of the ritual monuments and the quality of the grazing area. Timberlake suggests, "... the process of prospection may well have been a subsidiary activity of transhumance agriculture, and may thus have been linked with the role of pastoralists in the uplands" (2001, p.184). It is possible that the tin deposits were discovered at a later time. If this were the case, then what impact would this have had on the development of the settlement? This may explain the unusual statistical pattern in the viewsheds of the valley bottom; perhaps the western houses were built once the tin was discovered or was being exploited to a greater extent and the inhabitants wanted to maintain some form of visual contact with the extraction area.

Further statistical testing

In order to test the hypothesis that the houses were placed to have visual contact with the tin-streaming areas, I conducted further statistical testing. I undertook a spatial statistical test that compares the area of a specific type of phenomenon that can be seen from the houses, using the Monte Carlo results as outlined above. I have shown that certain areas of the landscape do seem to have been more visible from the actual house locations than would have been expected by chance alone. These areas mostly coincide with valleys in the landscape, which is where most of the tin-streaming occurs.

There are two different types of tin-streaming, eluvial and alluvial. Eluvial tin-working involves excavation of a (usually dry) valley bottom and requires the tin-workers to bring water in from outside. In the post-mediaeval period this was achieved by redirecting water using a series of leats and reservoirs. Eluvial tin often shows itself as shode (tin-stones) appearing on the surface which can be collected. By contrast, alluvial tin is streamed from the edges of river valleys, with the water helping to wash away the excess material leaving the cassiterite *in situ.*

The areas around Leskernick Hill have been exploited in the past for both eluvial and alluvial tin, the locations of which have been recorded by the English Heritage survey (Herring et al. 2002). Whilst there is no direct evidence that these areas were exploited in the Bronze Age, they do indicate areas of possible tin extraction, which would likely have been shown to the Bronze Age inhabitants also by the shode on the surface.

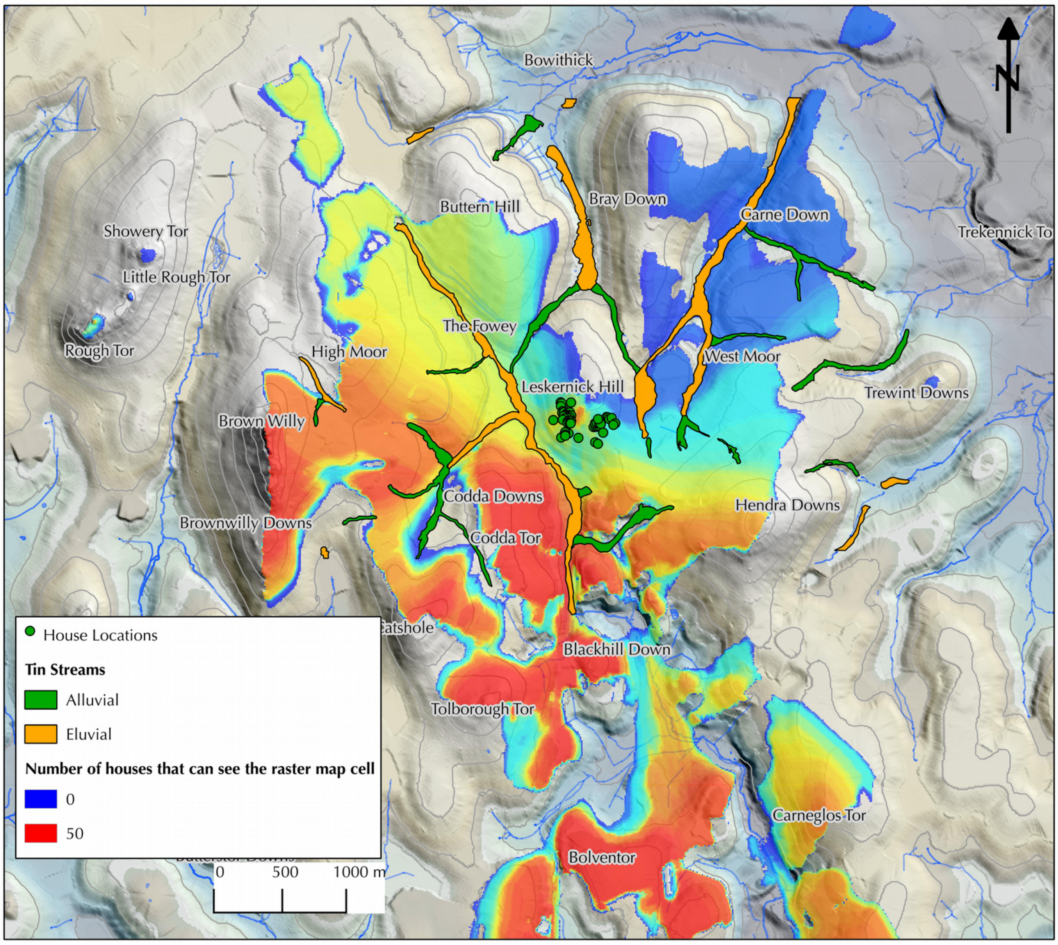


Figure 45 - Areas of tin extraction (data taken from Herring et al. 2002)

I have therefore used these areas as a proxy for the Bronze Age tin extraction. As can be seen in Figure 45, the tin-streaming areas surround the whole of Leskernick Hill. Therefore, for this exercise I decided to again treat the western and southern settlements as one entity and used the cumulative viewsheds that I calculated earlier, which show the number of houses that can see an individual raster map cell. By summing the count of raster map cells that fall within both a cumulative viewshed and an area of tin extraction, it is possible to calculate the total area of tin-streaming that can be seen from the cumulative viewshed. I can then repeat this exercise for all of the Monte Carlo cumulative viewsheds (the run of forty-nine cumulative viewsheds which were created using random house locations constrained within the entire settlement area). Finally I can compare those results to the same calculation for the cumulative viewshed of the actual house locations. This analysis gives the total number of cells within the tin extraction areas that can be seen for each of the Monte Carlo viewsheds along with the total number of tin cells that can be seen from the cumulative viewshed of the actual house locations.

When these results are plotted on a histogram, as would be expected, the random house locations show a roughly normal distribution for the eluvial tin location. As can be seen from Figure 46, sixteen of the random house cumulative viewshed runs could see between 60000 and 62500 cells that contain eluvial tin.

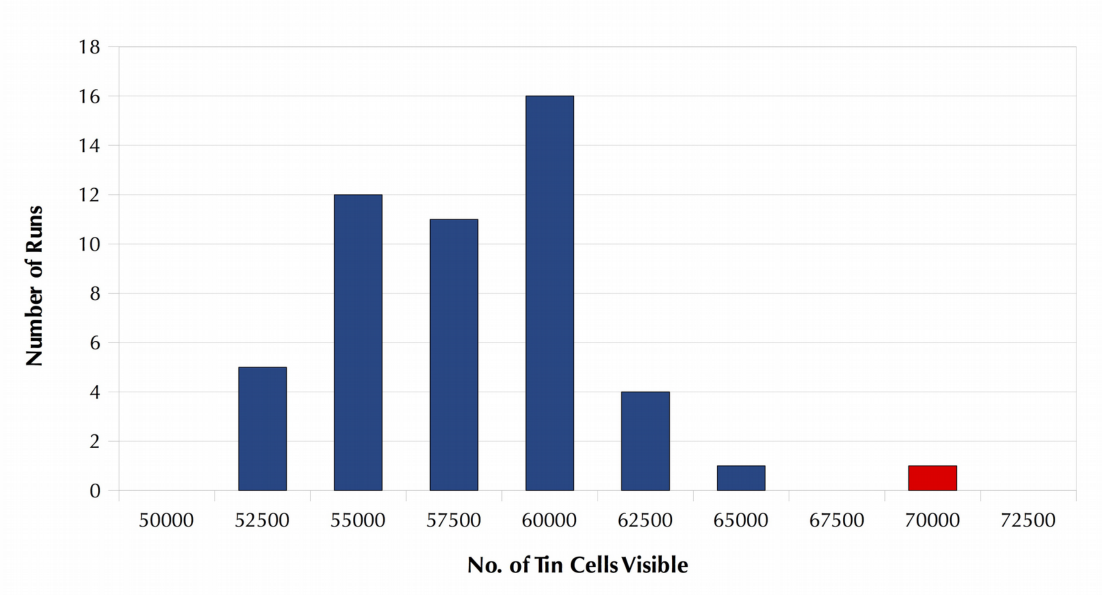


Figure 46 - Histogram showing the total number of eluvial tin cells that are seen by the cumulative viewsheds of the random houses. The cumulative viewshed from the actual house locations is shown in red.

However, the result of the actual house locations (shown in red) is plotted as a clear outlier, with a considerably larger proportion of the tin areas being visible from the actual houses than from the set of fifty random house locations. This serves to support the results from the spatial confidence mapping, which shows the valley to the west of the settlement (a large area of eluvial tin extraction) as being unexpectedly visible. The results, therefore, may well have been skewed by this large area – however, the pattern for the alluvial tin areas is almost exactly the same – with the view from the actual house locations also being an outlier from the random samples (Figure 47).

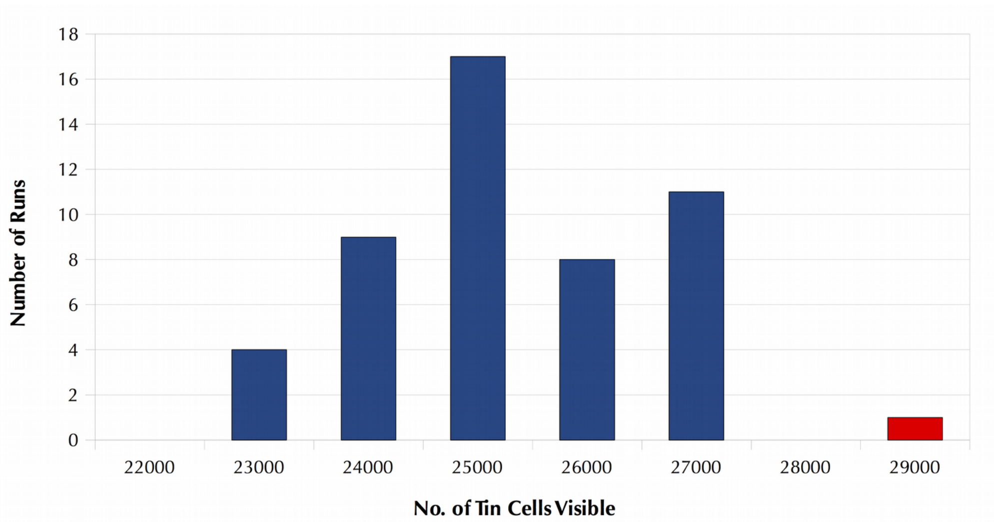


Figure 47 - Histogram showing the total number of alluvial tin cells that are seen by the cumulative viewsheds of the random houses. The cumulative viewshed from the actual house locations is shown in red.

By summing the total number of houses that can see each cell, the analysis is not taking account of the fact that fifty houses may be seeing only a small part of the area, or one house may be seeing all of the area – the raw totals do not elucidate the possibility of the internal distribution of the views amongst the houses. Therefore, a number of different derivatives of the total can be plotted, to reduce and explore this effect. For instance, a more robust method would be to plot the median and inter-quartile range of the counts. As can be seen in Figure 48 and Figure 49, the pattern still holds for the eluvial tin areas, with a generally normal distribution for the random runs and the run from the actual houses sits as a clear outlier.

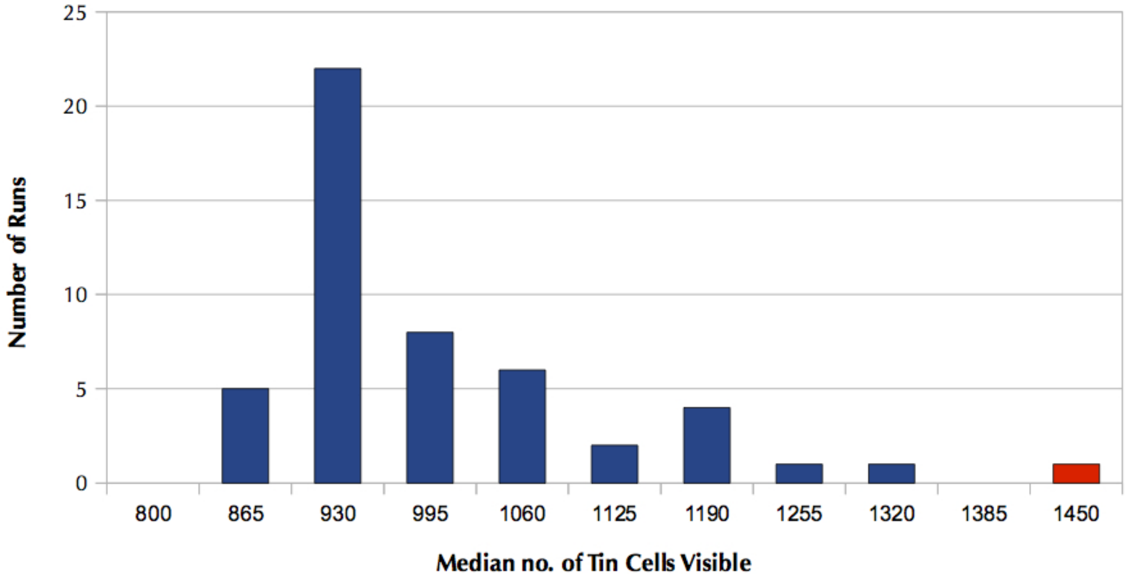


Figure 48 - Showing the median cell count for the eluvial tin areas, with results from actual house locations shown in red.

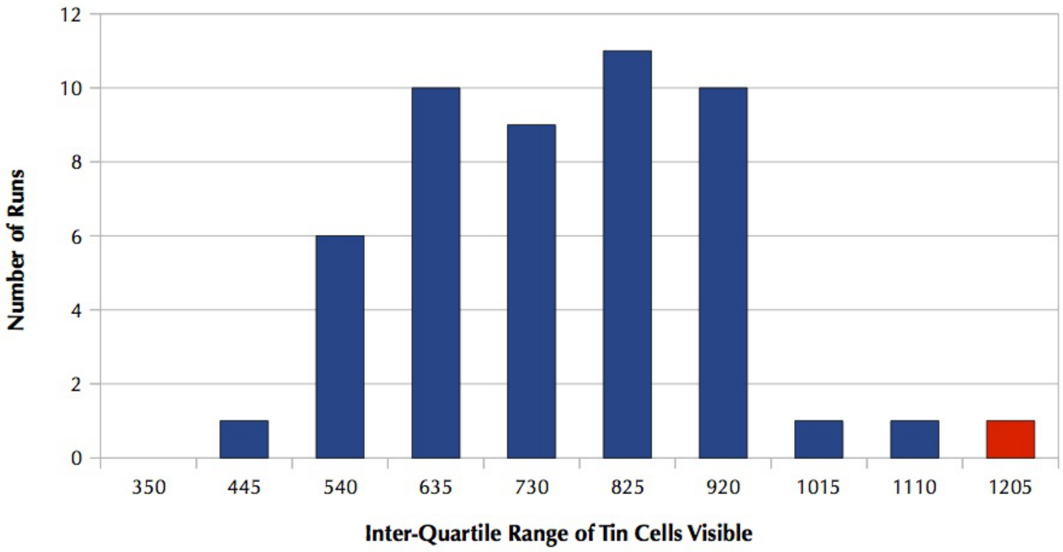


Figure 49 - Showing the inter-quartile range of the cell counts for eluvial tin areas, with results from actual house locations shown in red.

When the same analysis is applied to the alluvial tin areas, the pattern is slightly different, in that the actual house viewshed is not an outlier when the inter-quartile range is plotted (Figure 50; Figure 51).

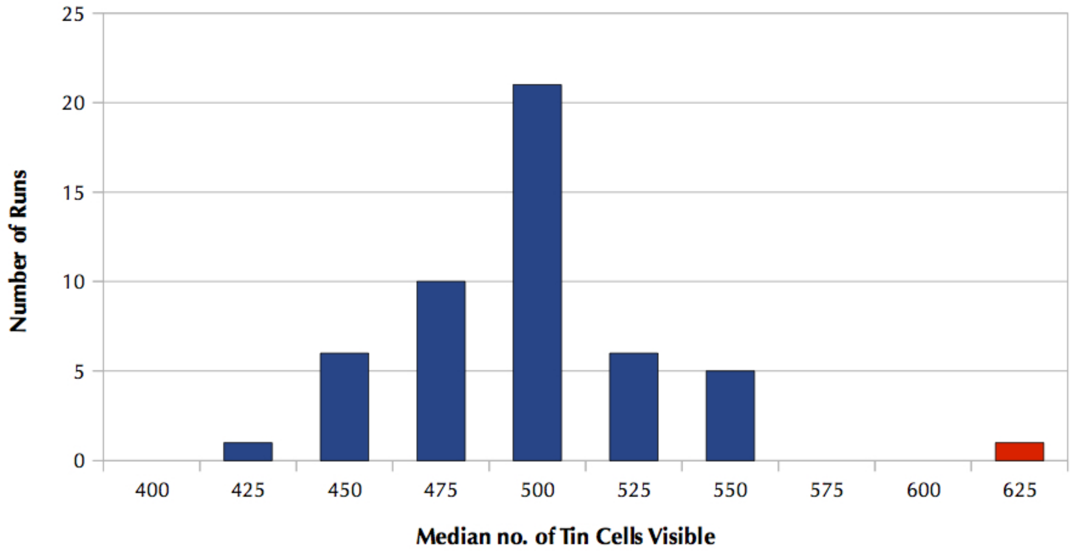


Figure 50 - Showing the median cell count for the alluvial tin areas, with results from actual house locations shown in red.

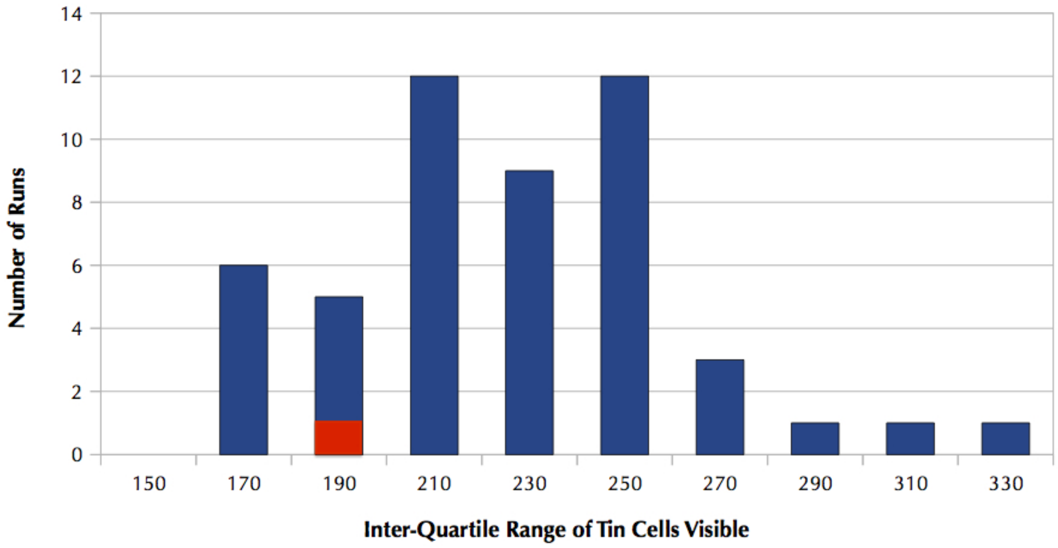


Figure 51 - Showing the inter-quartile range cell count for the alluvial tin areas, with results from actual house locations shown in red.

Using the inter-quartile range of the calculations in this manner for the alluvial tinning areas, would seem to suggest that the pattern that was observed from the raw cell counts (showing the actual house visibility as an outlier) was a little skewed and may have been the result of one or more of the houses having a large view of the alluvial tinning areas, but one that does not hold for the rest of the houses. This may suggest that the houses were not placed within the overall settlement area for observation of the alluvial tinning areas. This overall pattern can also be seen when the Monte Carlo runs are plotted in using an Empirical Cumulative Distribution Function (as described previously), Figure 52 and Figure 53 show each of the random runs and how many of the houses can see the cell count (i.e. the tin-bearing cells) or fewer. The red line shows the result for the actual houses.

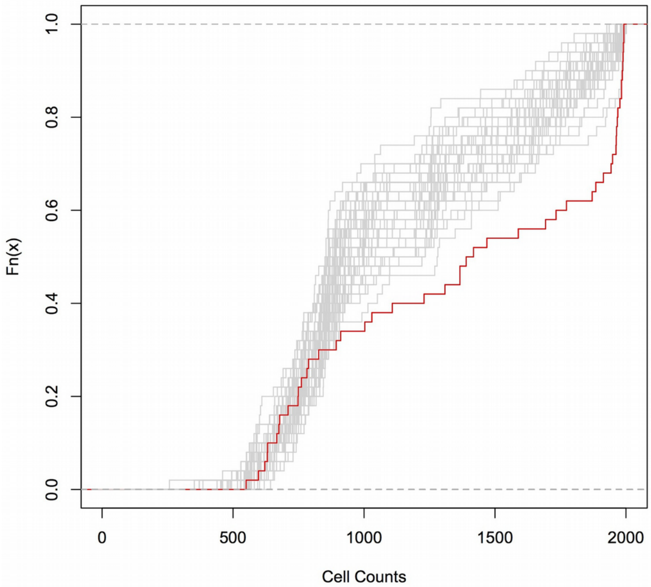


Figure 52 - ECDF plot of the eluvial tin areas

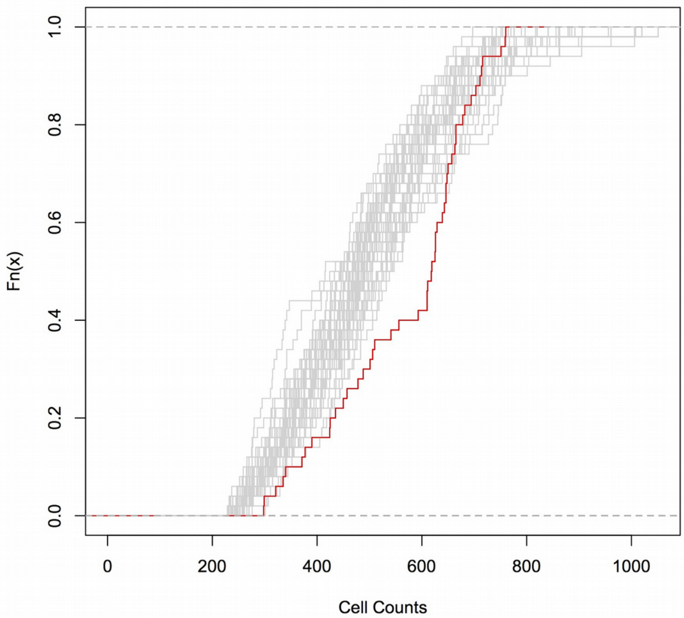


Figure 53 - ECDF plot of the alluvial tin areas

It is clear that the actual houses fall outside the 'normal' envelope on both the eluvial tin and the alluvial tin areas, meaning that they are statistically unlikely to have had those views of the tin areas if the houses were placed by chance alone. The eluvial pattern is more pronounced, further reinforcing the results of the previous tests. Due to the tinning areas being present on all sides of Leskernick Hill, these analyses were undertaken against the entire settlement area, with no distinction between the southern or western settlement areas. As I will demonstrate below, when a slightly more macro-scale is looked at, these results become even more informative.

Changing the scale

As I have demonstrated, the analysis of the viewsheds from the houses do seem to show that the views of both the eluvial and alluvial tin areas are unusual when compared with the expected pattern. It would appear that the views of the eluvial tinning areas are more pronounced. It is important to remember that the above analyses using the spatial confidence maps are a product of a constrained set of areas in which random points are placed. The experiments are therefore only testing whether the micro-placement of the houses within the already existing areas of settlement makes a difference to the cumulative viewshed, not whether the settlement areas themselves on the slopes of Leskernick Hill are significant within the wider landscape.

There have been a number of reasons posited for the placement of the settlement as a whole on the south slopes of Leskernick Hill, some of which I have already discussed. For instance, if the ritual area (the stone row and circles) was created before any actual settlement, then houses may have built to to take advantage of being in close vicinity to these monuments. Another reason may have been to take advantage of the building materials (i.e. stone) that would have been available, as the clitter streams (masses of granite) only occur on the southern side of the Hill. The prevailing wind over Bodmin Moor is from the north-east, and therefore it may have made sense to place their houses on the southern side, nestled within the lee of the Hill (Tilley 1996). The western part of the settlement is built within the clitter streams, with some houses taking advantage of the earth-fast boulders to act as backstones for the construction. Yet, when one attempts to walk around the settlement as the Stone Worlds team explain:

> “...the ground is so uneven, so stony, so difficult to navigate. Why didn't they build below the Hill, as at Roughtor? … it seems that, for them, it was important to live in close proximity to the ancestors or ancestral beings. There was a reciprocity – they could nurture the stones and, in turn, the stones would care for them.” (Bender et al. 2007, p.109)

There was clearly a reason or reasons to choose to settle where they did, and from my GIS analysis it is tempting to suggest that the tin resources may have played some part in this decision. However, until now I have only been testing the micro-placement of the houses with the settlement area, not the position of the settlements themselves. It may be that the unusual results from the analysis of the micro-placement of the houses that suggests they were placed to have visibility of the tinning areas is simply a fluke, due to the position of the settlement itself; alternatively it may be that the settlement as a whole was deliberately placed to take advantage of these views. In order to test this, it is necessary to widen the scale of my analysis and test the whole of the Hill.

Therefore, to test which parts of the hill may be the best places from which to view the tin-streaming areas, I created a different type of viewshed, which I have called the *visibility field* (Figure 54). This involves first creating an individual viewshed for every raster map cell over the entirety of Leskernick Hill. These viewsheds are then coded with the number of tin-bearing cells that can be seen from that location. The result is a map that shows the cells on the Hill that afford the greatest view of the tin fields.

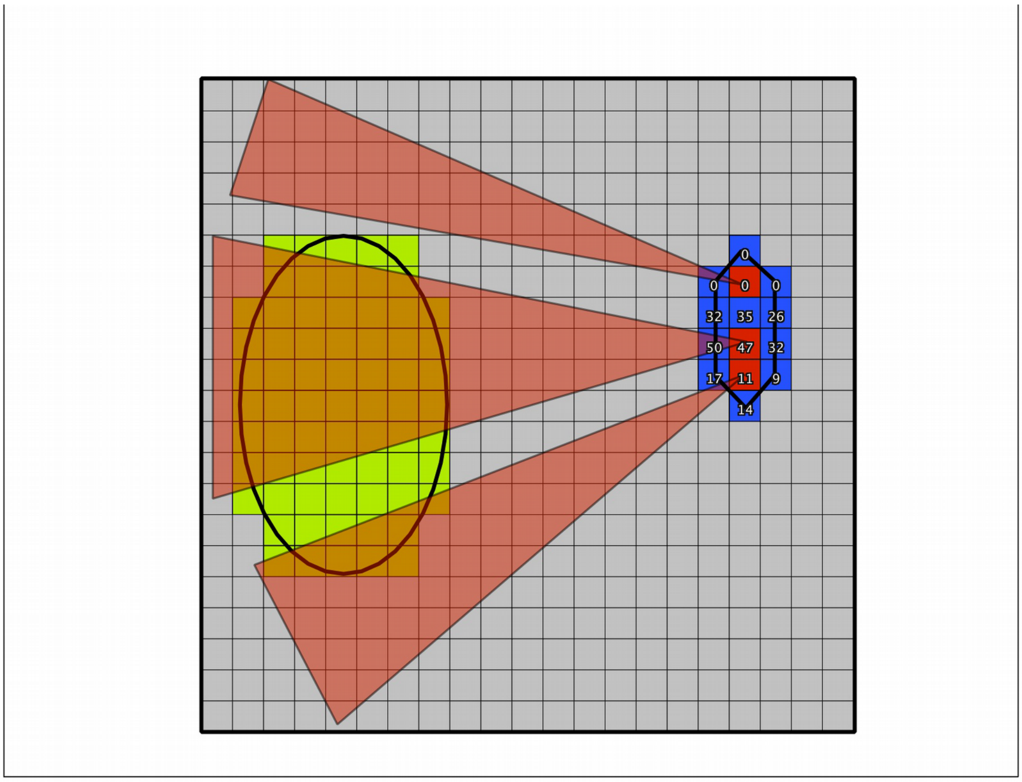


Figure 54 - The creation of a visibility field. Individual viewsheds are calculated for every cell that falls within the visibility field (shown in blue). Each cell of the visibility field is then coded with the total number of the cells in the target area (green) that fall within its viewshed.

This type of analysis was first used by Mark Gillings when looking at the amount of sea that could be observed from various positions on the island of Alderney (2009, pp.344–345). Gillings uses what he terms 'affordance viewsheds' to suggest areas of Alderney that may have commanded expansive sea views, and hence may have been attractive for monument construction. In my case, I am using a similar methodology to investigate which areas of the Hill have the most expansive views of the tin fields and hence may be attractive for settlement if observation of the tin fields was important. As Figure 55 convincingly shows, the houses of the 'Great Compound' in the western settlement do seem to be clustered in the area that offers the greatest view of the eluvial tin streams, whereas the houses of the southern settlement are placed in an area of lower visibility.

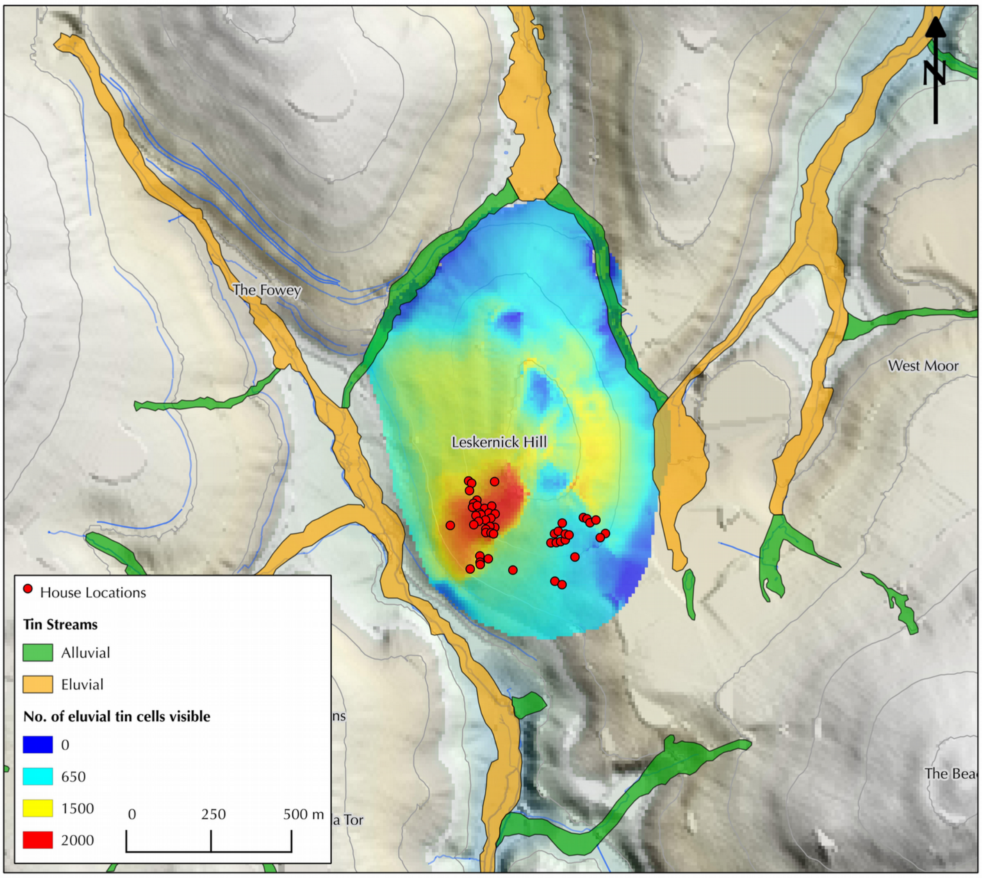


Figure 55 - A visibility field of Leskernick Hill coloured to show the cells that can see the most of the eluvial tinning areas

It is intriguing that the results of the various analyses show a definite, statistically significant pattern: that the micro-placement of the houses within the western settlement area seems to be correlated to the available views of the tin streams. When this analysis is widened to take account of the entire Hill, it would seem to suggest that not only were the houses placed within the settlement areas to take advantage of the views of the tin fields, but this pattern also holds for the placement of the settlement itself. The western settlement would appear to have been placed within the area of the Hill that has the best views of the eluvial tin resources.

Following this, it is also possible to undertake some tests to see if the other archaeological assumptions are borne out, for instance, Herring's suggestion that the southern settlement was placed to respect the ritual area. As I have shown earlier, the spatial confidence mapping suggests that the houses of the southern settlement were placed to have a view of the northern stone circle that would not have occurred had they been placed randomly. By taking the visibility field of the entire hill and coding each viewshed with the number of cells of the ritual area that it can see, the pattern clearly shows the houses of the southern settlement are built in the ideal location of the visibility field to command the sight of the ritual monuments (Figure 56).

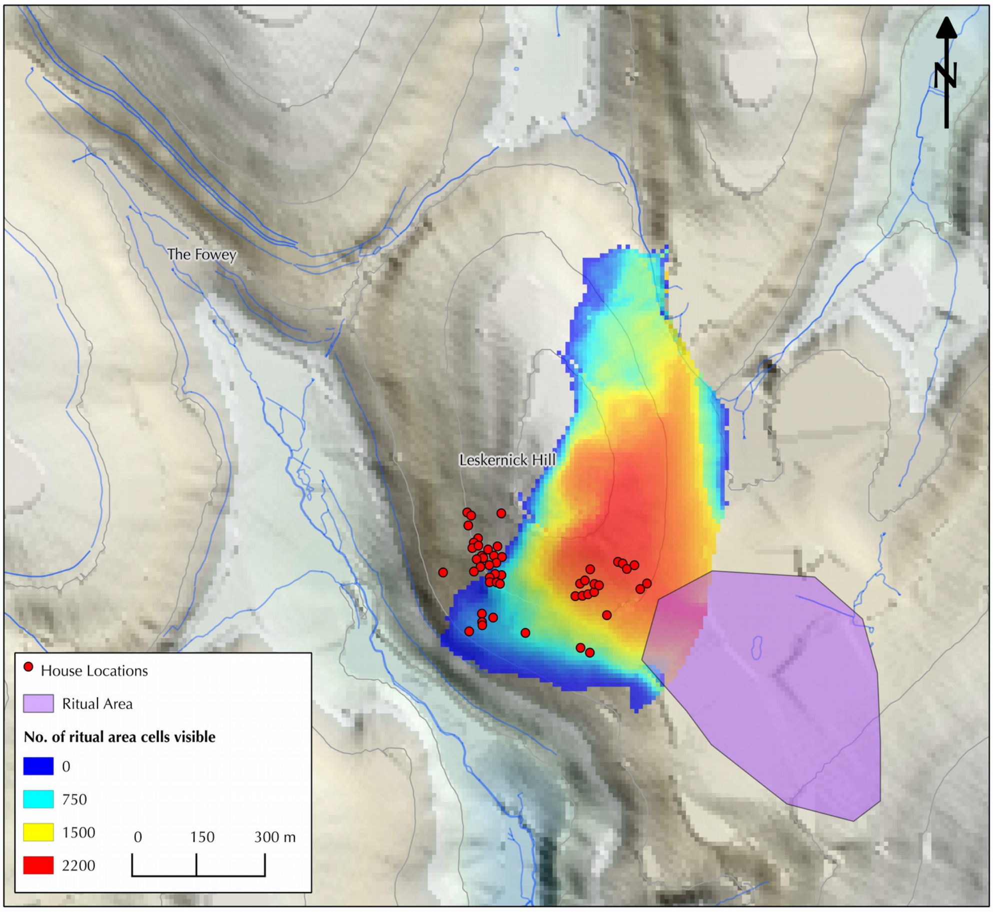


Figure 56 - Areas of Leskernick Hill coloured to show the cells that can see the most of the ritual area

The GIS Approach

Throughout this chapter I have used various GIS techniques to analyse the settlement pattern of Leskernick Hill. I have assembled a spatial database from a wide range of sources and have used this as the basis for performing a number of different statistical tests. This GIS database can now be taken forward and used as the basis for the embodied GIS (Chapter Seven).

In order to investigate the reasons for the house placement on Leskernick Hill, I began by looking at the micro-placement of the houses within the settlement area. Being led by Bender *et al.*'s assumption that the houses were placed to command a good view of the natural and cultural monuments (the stone row, stone circles, Brown Willy and Roughtor), I calculated a large set of cumulative viewsheds. The subsequent analyses (using Monte Carlo simulation and my new 'Spatial Confidence' mapping) suggest that *no matter where* in the entire settlement the houses were placed, they would have had a good view of the natural features. These analyses also revealed a hitherto unexpected pattern, that the houses in the settlements may have been individually placed to command a view of the Fowey river valley. Zooming in even further I studied each of the parts of the settlement individually (western and southern), the resulting spatial confidence maps confirmed that the houses in the western settlement did command a view of the valley that would not have occurred unless they were specifically placed in those exact locations. The unexpected views from the southern settlement showed there was some kind of visual relationship with the northern stone circle, which seems to confirm Herring's view that the houses in the southern settlement were placed deliberately to respect this monument.

The results from these analyses led me to investigate the reason for the preferential views of the river valley, an area which is rich in tin. The Stone Worlds team suggest that the presence of tin *may* have been a reason for the settlement on the Hill, but with no direct archaeological evidence for this, they did not pursue this hypothesis further. By comparing the amount of tin-bearing areas that could be seen for forty-nine sets of randomly-placed houses with the amount seen from the actual house locations, I was able to demonstrate that the houses do seem to have been placed within the settlement area to command an unusually complete view of the tin-bearing areas, especially the eluvial tinning areas.

This brings into play the reason for the settlement being on that particular part of the Hill, rather than on the northern or eastern side. As Bender *et al.* point out, the other settlements on Bodmin Moor are often on the northern slopes of the hills (2007, p.109). By creating 'visibility fields' I was able to take a more macro view of the Hill and show which parts of the Hill afforded the best views of the tin fields. It clearly shows the western settlement is placed in the ideal location. In addition, when I looked at the visibility field of the ritual area, the southern settlement is also ideally placed to view this.

By using this set of sophisticated GIS analyses, I have been able both to provide supporting evidence for the hypothesis that the southern settlement was placed for a preferential view of the ritual area, in particular the northern stone circle, and also to demonstrate that Bender *et al.*'s suggestion that views to Roughtor or Brown Willy were important would have held no matter where the inhabitants had placed their houses in the settlement area. The analyses have also highlighted the possible importance of the tin deposits. As I have shown in Chapter Four, it is a long held belief that the tin trade was of importance to the upland communities of the south west, but there has been little direct evidence from any archaeological investigations to support this, especially not from Leskernick Hill. The GIS analyses suggest that the houses and settlement on the Hill may well have been placed to deliberately have some kind of visual connection with the tin fields, perhaps to enable monitoring or observation of any tin extraction.

I have shown that GIS analyses can produce interesting results, and ones that warrant further study. However, at this stage, all of my analysis has been undertaken within a computer, using a modelled landscape – and as explained in Chapter Three, is slightly divorced from the real world. Essentially the GIS analysis is sitting on the Virtual Reality end of Schnabel scale. In the following chapter I will explore the other end of the Schnabel scale, and use phenomenological techniques to investigate the Real Reality of Leskernick Hill and see if other questions are raised by taking a purely phenomenological approach to the Hill.

Chapter 6 - The Phenomenological Approach

In the previous chapter I used traditional, albeit statistically sophisticated, GIS analyses to approach the settlement on Leskernick Hill, all undertaken within the confines of a computer laboratory. In this chapter I invert this and concentrate instead on experiments undertaken within the landscape itself.

As outlined in Chapter Four, Leskernick Hill has previously been subject to a number of seasons of what is arguably the most intensive phenomenological fieldwork so far undertaken in the UK. In this chapter I will discuss and build upon this work, whilst bringing newer methodologies to bear on Leskernick Hill to attempt to further explore the intricacies of the settlement. Taking my lead from Hamilton and Whitehouse's phenomenological work in the Italian Tavoliere Plain, I first undertake *Phenomenological Site Catchment Analysis*, to explore the landscape surrounding the Hill. I then go onto investigate aspects of sound and communication across the Hill, testing the visibility and audibility of some of the areas, including the river valleys. Following my previous discussions of the possible importance of tin to the inhabitants, I also examine one particular class of feature of the Moor that I have not yet discussed: the hollowed-out 'solution basins' that have been cut on the tops of many of the tors in the Moor. Finally, I draw together conclusions from the phenomenological approach and how this contrasts with the previous GIS analysis, and how the two different methods can be taken forward to form the embodied GIS.

Phenomenological Site Catchment Analysis

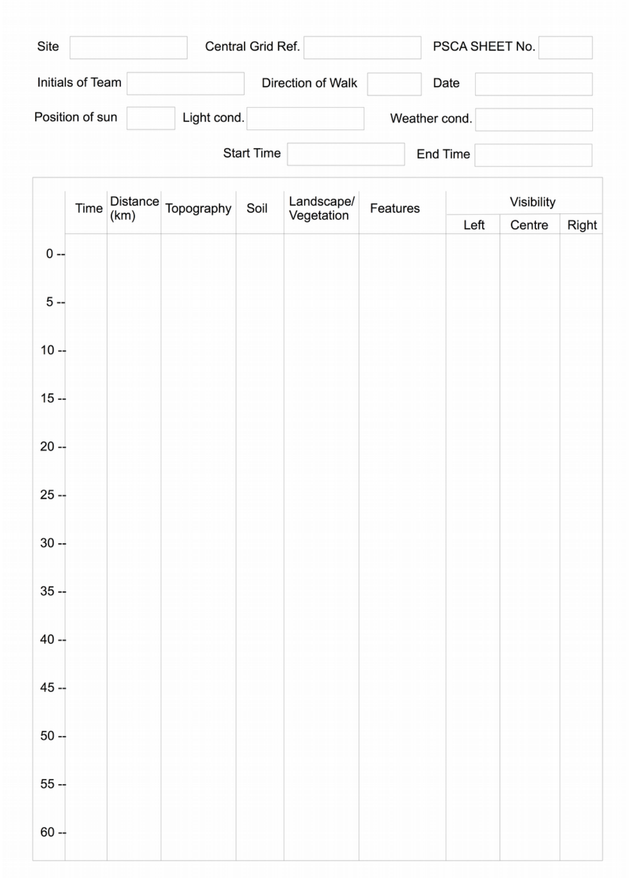
As discussed in Chapter One, Hamilton and Whitehouse, in their work on the Tavoliere plain, attempted to challenge the strong critique that “descriptions of phenomenological fieldwork have not made their practical methodology (as opposed to their theory and observations) explicit” (Hamilton *et al.* 2006, p.32; and see Fleming 2006; Johnson 2006; Brück 2005). They present a number of different phenomenological techniques: some challenge the preponderance for phenomenologists to traditionally focus on vision, some challenge the traditional focus on ritual landscapes as opposed to domestic, and others challenge the traditional view of the phenomenologist as a "lone male observer" (Hamilton *et al.* 2006, p.35). All of their proposed techniques have a clear and straightforward methodology, which strives to be as repeatable as possible. This type of phenomenological fieldwork marries well with the ethos of the embodied GIS – that is, to create a working environment and set of practices that allow the repeatability of a formal experiment, without stifling the subjectivity of the body-centred approach.

One of the techniques they used was Phenomenological Site Catchment Analysis (PSCA). This builds on the classic landscape exploration technique employed during the 1970s and 80s (Roper 1979; Jarman *et al.* 1972; Vita-Finzi & Higgs 1970; and is still used for some analysis, see Li 2013) in which a radius of a one hour walk is established, and all resources (springs, wells, rivers, *etc.*), soil types and land usages are recorded in the four cardinal directions (north, south, east and west). The original methodology described by Higgs (1975, pp.223–224) has been criticised: with regard to its theoretical underpinnings in environmental determinism (Wheatley 1993), its reliance on a strictly geometric view of the (modern) landscape, which does not take account of the subtleties of resource collection and management (i.e. it presumes the subsistence economy can be separated out from other aspects of past lives), and the fact that it does not allow for the landscape to have changed since prehistory (see Hamilton *et al.* 2006, pp.54–55 for further discussion). However, Hamilton and Whitehouse saw some value in the site-centred analysis and adapted the original Site Catchment Analysis methodology to include a record of the visibility of various landmarks in the landscape, and also "impressions of the nature of the journeys within a site's territory ... in terms of openness/restriction of views, difficulty of terrain and so on" (Hamilton *et al.* 2006, p.54). They also concentrated on the moments and location in which sites first came into view, and the moment and location when it becomes continuously visible, as these points are "likely to have been significant, particularly in social terms" (Hamilton *et al.* 2006, p.54).

PSCA on Leskernick

I followed Hamilton and Whitehouse's methodology in my exploration of the

Phenomenological Site Catchment of Leskernick Hill. Where they undertook the analysis on a number of different sites on the Tavioliere Plain, I used the methodology to create a full picture of only the settlement on Leskernick Hill. I created my own recording sheets (Figure 57), drawing on Hamilton and Whitehouse's published examples, and along with a field team of six other people (both male and female professional archaeologists currently employed by L – P : Archaeology) we undertook the analysis in October 2012 and February/March 2013.



Site | Central Grid Ref. | PSCA SHEET No.

Initials of Team | Direction of Walk | Date

Position of sun | Light cond. | Weather cond.

Start Time | End Time

	Time	Distance (km)	Topography	Soil	Landscape/ Vegetation	Features	Visibility		
							Left	Centre	Right
0									
5									
10									
15									
20									
25									
30									
35									
40									
45									
50									
55									
60									

Figure 57 - The PSCA recording sheet adapted for use at Leskernick Hill

The methodology involves walking a radial line along each cardinal direction from the site for a total of one hour. In order to properly record the changing views, sounds and smells we stopped every five minutes and recorded the soil, topographic, landscape and vegetation features and anything else of note. We also recorded what landmarks could be seen to the left, centre and right of the investigator. A further sheet was completed for the return journey, some elements were repeated (for instance the topography and soil information). In addition to the recording sheet, as per Hamilton and Whitehouse's methodology, a longer set of notes were taken describing the past fifteen minutes of the journey. The same methodology is used for the return journey, with the exception that elements which would not have changed (such as topography and geology) were not recorded. However, the investigator's corporeal and affective reactions to those elements was recorded, *e.g.* the different effects on the body that walking up or down a steep slope entails. At the end of each journey the investigators' most significant moments were also recorded. There was no guidance given on the nature of the 'moments'; instead, the investigators were given free rein to decide what they considered their most significant moments.

Each of the investigators had spent at least two days on Leskernick Hill prior to undertaking the PSCA, and hence had some limited familiarity with the major landmarks; however, apart from the walk into the Moor (from the north), no-one had explored beyond the limits of the lower slopes of Leskernick Hill. The investigators were in pairs at all times, and were also equipped with a head-mounted camera in order to record the sights and sounds of the journey. A side-effect of this meant that a 'running commentary' on the journey was also created, capturing the conversations and observations of the investigators as they walked the landscape. The head-mounted video also provides a record of the PSCA walks, that can be replayed by researchers and if necessary, reinterpreted. On some occasions the weather was too bad to write on paper recording sheets, therefore audio notes addressing each of the recording sheet prompts were taken and transcribed at later date. Each team also carried a GPS logger, enabling their exact paths to be plotted. The gazetteer reproduced in Appendix Two provides panoramic views from the highest points of some of the hills, and should be consulted alongside the results presented in this chapter.

By using this methodology it was possible to create an average site catchment area for Leskernick Hill.

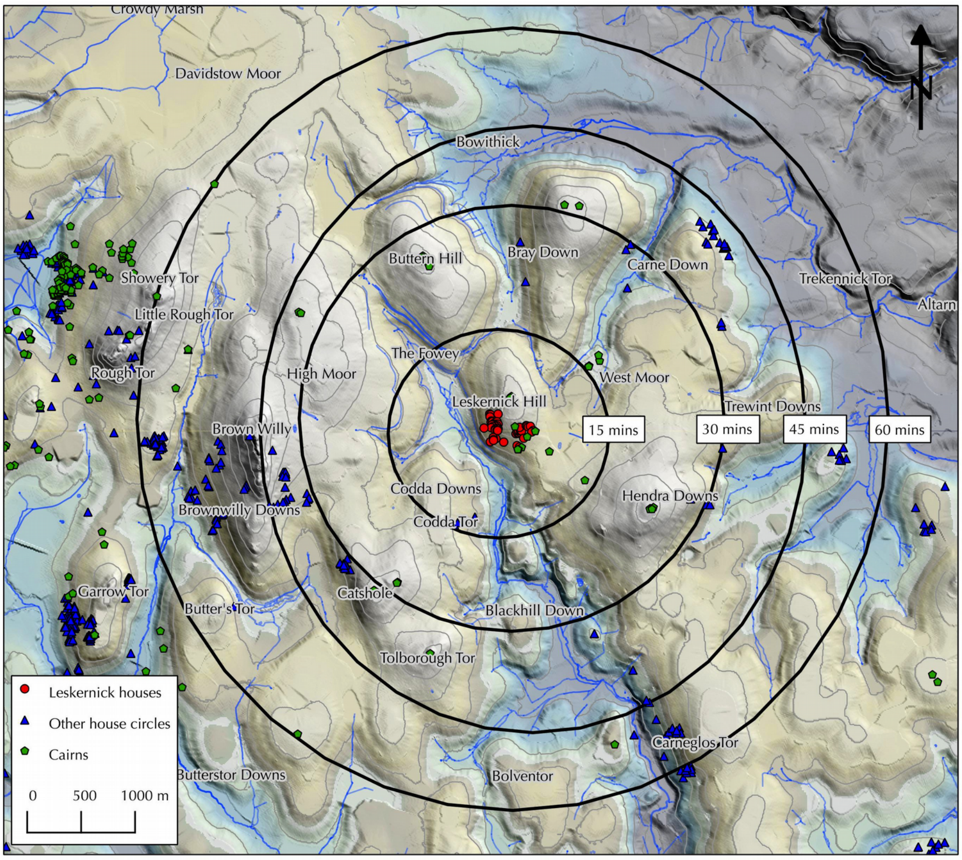


Figure 58 - The Phenomenological Site Catchment Analysis area for Leskernick Hill, showing the distance that can be walked within one hour.

As can be seen from Figure 58 the catchment area designated by the PSCA covers the majority of the bowl of hills in which Leskernick sits. This result surprised me, as when one is on the Hill there is a feeling of isolation, a feeling of being behind a barrier of quite imposing hills with a long walk out from every direction. Yet when undertaking the PSCA, it quickly becomes clear that Leskernick Hill is not entirely isolated and, in fact, it is a relatively short walking time until one comes into contact with the other Bronze Age settlements of the area and surrounding ritual monuments.

Time Travelled (in minutes)	Cairns	Water Sources	Tors and Hilltops	Other house circles	Tin streams
5	6				
10	9	Fowey River			alluvial, eluvial
15	10	Fowey River		4	alluvial, eluvial
20	12	Fowey River, stream between Bray Down and Buttern Hill, stream between Carne Down and West Moor	Codda Tor	4	alluvial, eluvial
25	20	Fowey River, stream between Bray Down and Buttern Hill, stream between Carne Down and West Moor	Codda Tor, Buttern Hill, The Beacon	5	alluvial, eluvial
30	26	Fowey River, stream between Bray Down and Buttern Hill, stream between Carne Down and West Moor	Codda Tor, Buttern Hill, The Beacon, Catshole Tor, Blackhill Down	11	alluvial, eluvial
35	32	Fowey River, stream between Bray Down and Buttern Hill, stream between Carne Down and West Moor, stream by Trewint Downs	Codda Tor, Buttern Hill, The Beacon, Catshole Tor, Blackhill Down, Tolborough Tor, Trewint Down	43	alluvial, eluvial
40	33	Fowey River, stream between Bray Down and Buttern Hill, stream between Carne Down and West Moor, stream by Trewint Downs	Codda Tor, Buttern Hill, The Beacon, Catshole Tor, Blackhill Down, Tolborough Tor, Trewint Down	56	alluvial, eluvial
45	33	Fowey River, stream between Bray Down and Buttern Hill, stream between Carne Down and West Moor, stream by Trewint Downs, stream by Butter's Tor	Codda Tor, Buttern Hill, The Beacon, Catshole Tor, Blackhill Down, Tolborough Tor, Trewint Down, Brown Willy	70	alluvial, eluvial
50	34	Fowey River, stream between Bray Down and Buttern Hill, stream between Carne Down and West Moor, stream by Trewint Downs, stream by Butter's Tor	Codda Tor, Buttern Hill, The Beacon, Catshole Tor, Blackhill Down, Tolborough Tor, Trewint Down, Brown Willy	83	alluvial, eluvial
55	35	Fowey River, stream between Bray Down and Buttern Hill, stream between Carne Down and West Moor, stream by Trewint Downs	Codda Tor, Buttern Hill, The Beacon, Catshole Tor, Blackhill Down, Tolborough Tor, Trewint Down, Brown Willy, Bolventor	124	alluvial, eluvial
60	38	Fowey River, stream between Bray Down and Buttern Hill, stream between Carne Down and West Moor, stream by Trewint Downs, stream between Brown Willy and Roughtor	Codda Tor, Buttern Hill, The Beacon, Catshole Tor, Blackhill Down, Tolborough Tor, Trewint Down, Brown Willy, Bolventor, Showery Tor, Little Roughtor, Roughtor, Butter's Tor, Butter's Tor Downs	159	alluvial, eluvial

Table 1 - Results of the Phenomenological Site Catchment Analysis

As can be seen from Table 1, within a ten minute walk, both water and tin are available and nine cairns can be visited. Within fifteen minutes, the four hut circles on the foothills of Codda Tor can be reached. Walking for thirty minutes brings one into contact with eleven other houses, five different hilltops and three different water sources. Finally, after an hour's walk it is possible to reach thirty-eight cairns, five water sources, all of the surrounding tors and hilltops and 159 hut circles. The SCA part of the PSCA demonstrates that the Leskernick Hill settlement was not in isolation at all and, disregarding questions of contemporaneity for the moment, by walking for less than an hour it is possible to visit over 100 other houses and more than thirty cairns.

Already this begins to give a different impression of the settlement: rather than existing within the bowl of hills, perched on the side of a windy slope, the settlement was actually part of a much larger community and one that was readily accessible. In their introduction, the Stone Worlds team also suggest that this is the case, talking of Leskernick existing within a nested landscape of different communities and settlements (Bender *et al.* 2007, chap.1). However, the body-centred perspective of the PSCA powerfully highlights this. The abstract analysis of a GIS could perhaps suggest this, but without actually having walked the landscape it is hard to imagine quite how connected Leskernick Hill really is. The PSCA fieldwork and methodology gave me a deeper understanding of the context of the settlement that was unexpected. By requiring the investigators to stop every five minutes and fill in a form, it ensured they took careful note of their surroundings, of how hard it is to walk, of whether their feet were wet, of which way the wind is blowing, of what they could hear and smell – the PSCA walks are a data-gathering exercise, but they are also a personal and body-centred journey through the landscape.

One of the problems with the PSCA methodology, as highlighted by Hamilton and Whitehouse (2006, p.64), is that the walks are undertaken along cardinal directions and are walked using a compass or GPS. This is quite difficult to achieve, especially within a landscape like Bodmin Moor, where the valleys are frequently boggy and there are areas of private land. It results in the need to keep stopping and starting the stopwatch and navigating around the features which breaks up the 'feeling' of a journey. Whilst this was undoubtedly true, we also found ourselves navigating less via the compass and more via prominent landmarks on the near and middle horizons. Hamilton and Whitehouse also comment on this, and note that a study of the specific landmarks used would be interesting, “both in terms of the relatively ‘fixed’ environment experienced in the settlement itself and the changing environment experienced by members of the community journeying through their village territory in pursuit of their daily tasks” (2006, p.64).

PSCA Leg	Landmarks Used	Significant Part of the Journey
Southern outbound	Top of Blackhill Down, Bolventor (modern settlement)	The blackness of the soil on Blackhill Down. Coming out of the bowl with the Fowey River valley opening up
Southern inbound	Top of Blackhill Down, Leskernick Hill	Leskernick settlement being revealed after cresting the hill between Leskernick and Blackhill Down
Eastern outbound	Black Rock (outcrop on the slope of the Beacon), after Black Rock all was done using compass	Black Rock being in view for most of the journey. Cresting Trewint Downs and feeling the emergence from the bowl of hills.
Eastern inbound	Black Rock, Leskernick Hill, Brown Willy	Leskernick Hill being in view for the majority of the trip.
Northern outbound	Modern farm building of Trevern farm	Gentle walk along river valley turning into views that feel like looking over a floodplain
Northern inbound	Leskernick Hill	Coming out of the tin stream on the north of Leskernick Hill and seeing the cairn on the top of Leskernick.
Western outbound	Rocky Outcrop on hill infront of Brown Willy. Middle cairn on top of Brown Willy	Standing on top of Brown Willy and looking over the landscape to Roughtor and the sea
Western inbound	Leskernick Hill	Leskernick Hill being in view for the majority of the trip. Being able to see through the hole in the Propped Stone

Table 2 - Showing the landmarks used during the PSCA logs, with a note of the most significant part of the journey

As can be seen from Table 2, the majority of landmarks that were used were (unsurprisingly) the tops of hills, with Leskernick Hill itself being used for navigation on the return journeys. Of the hills used, neither Blackhill Down, Bolventor or Black Rock have obvious extant cairns on them, the navigation instead being undertaken by pointing oneself at the summit. Black Rock is an outcrop of granite on the slopes of the Beacon, which stands out quite clearly on the horizon. Bolventor has a modern settlement on it, with Jamaica Inn (of Daphne Du Maurier fame) being quite an obvious navigational aid. The outcrop on the slopes of Brown Willy also does not show any sign of cultural modification. With the exception of the cairn in the middle of the ridge of Brown Willy, cairns were not used for navigation; rather the shape and form of the landscape itself was used (along with some modern buildings). This may of course be due to the arbitrary nature of the cardinal directions not pointing directly at cairns, but it shows a more practical, day-to-day approach to navigation is completely possible, *i.e.* “walk towards the rounded hill with black soil, and then on to the next one over the river”, rather than “head towards Grandpa's tomb and then turn left toward the cairnfield”.

The remarkable thing about the most significant parts of the journey, at least from the outbound legs, was the intense feeling of exiting the bowl of hills when the wider landscape was revealed. This was mentioned for each leg and is further evidence of the feeling of an enclosed landscape, separated from the 'outside'. The transcripts of the walks constantly refer to a feeling of having re-entered the 'real world' when the hills at the edges are crested.

> “You really feel as if you've come out of the enclosed bit of the moor, where Leskernick is, and you feel like you are out in the real world, as it were” - Southern Outbound 45 min stop

> “this is the last hump [Black Rock], you now really feel as if you are coming out of that enclosed space” - Eastern Outbound 20 min stop

> “Had to clamber a bit to get to the top [of Brown Willy], but obviously once you get to the top – BOOM! The whole of the vista opens up, pretty impressive stuff” - Western Outbound 45 min stop

This is also true of the northern outbound walk in which, rather than cresting a hill, followed the river valley between Buttern Hill and Bray Down. This trip is described as feeling very enclosed:

> "Once you come off the back of Leskernick Hill, the views are quite enclosed, you can't see anything to the left" - Northern Outbound 15 min stop

until one is through the valley and the wider landscape is revealed:

> "Everything opens out in front of me, [it] really feels like a floodplain more than anything else" - Northern Outbound 40 min stop

This feeling of enclosure was very evident in the transcripts of the trips, and surely it must have been similar for the inhabitants of Leskernick. There is no mention of Leskernick feeling sheltered, indeed it would seem that once you are inside the bowl of hills, the landscape again feels quite open

> "its a great view from up here into the world of Leskernick" - Southern Inbound 5 min stop

With one transcript of the eastern inbound trip explaining that once you crossed into the world of Leskernick it was like the:

> "centre of the moor opening up" - Eastern Inbound 10 min stop

Leskernick, however, feels like it is separate place from the wider world, and when you exit (at generally 25-40 minutes walk from the settlement in all directions) it feels as if you are leaving a self-contained world.

> "Once you are getting towards it [Trewint Down] everything else drops away and you're really looking out over this much lower, flatter area. Trewint Down really looks like somewhere you would put a look-out-point, the edge of the moor" - Eastern Outbound 25 min stop

The outbound journeys record the feeling of exiting the world of Leskernick, and unsurprisingly, the inbound journeys record the opposite. Certainly the return journeys had a different effect on the investigators:

> “As they said in their work on the Tavoliere Plain, the return journey feels a bit like going home, and that's how it feels here ... a different feeling on this trip” - Western Inbound 15 min stop

> “Then [it] is just a gentle slog up the slope to house 33 where we are going to have a sit down and have an apple... home.” - Southern Inbound 55 min stop

> “...there is a very clear view of the settlement, I can see everybody beavering away. It looks very cosy [from] up here, now that I'm used to sitting in those huts... nice and sheltered” - Western Inbound 40 min stop

As touched on above, Hamilton and Whitehouse place a special emphasis on the moment that the settlement is first able to be seen and then when it can be seen continually. This was acutely observed during the southern inbound trip, with Leskernick Hill first being in view just five minutes from the start of the walk:

> “its a pretty impressive view right down to Leskernick Hill” - Southern Inbound 5 min stop

It remained in view for another five minutes until:

> “Basically Leskernick has been in view all the way down here, its just about to disappear behind Blackhill Down” - Southern Inbound 10 min stop

After disappearing behind Blackhill Down, the Hill appears again at the twenty-five minute stop:

> “The site is in view and will probably be in view for the rest of the walk... enclosure walls easily discernible” - Southern Inbound 25 min stop

This was not to be the case, however, and at thirty-five minutes, Leskernick becomes hidden again behind a small unnamed rise to the south of Leskernick Hill:

> “Leskernick is obscured behind the back of the unnamed hill to the south of Leskernick” - Southern Inbound 35 min stop

> “We have just got up to the top of the unnamed hill... and it is sort of the Reveal as you come up

> over the crest it. Leskernick appears and then Buttern Hill appears on the left and then [Bray Down] peeks over on the right hand side" - Southern Inbound 40 min stop

Even after cresting the top of the unnamed hill, the settlement on Leskernick Hill goes out of view again, due to a river valley that is not immediately obvious:

> "It's kind of an interesting view up here as you can't tell there is a massive valley floor as you come over the hill – which we are going to have to cross in a minute" - Southern Inbound 40 min stop

Until finally, once the river is crossed and the valley side is crested:

> "After that Reveal on the top of the unnamed hill, this is really quite nice to come down and then back up again, to see it [Leskernick settlement] in all its glory" - Southern Inbound 50 min stop

Of course, to a certain extent in this walk the timing is arbitrary, depending on how fast or slow the investigators were walking, however, the feeling of intermittent visibility would be the same for anyone making this journey (allowing for the height differences of the individual investigators).

When coming in from the north, the settlement is not in view until the very last minute, due to it being on the southern slopes of Leskernick Hill, however, the cairn on top of Leskernick Hill becomes the focal point:

> "directly in front of us we have Leskernick visible, with its cairn on the skyline" - Northern Inbound 25 min stop

> "40 minutes in and we're on the top of Leskernick Hill, by the cairn – we found ourselves inexorably drawn towards it" - Northern Inbound 40 min stop

When coming from the east or the west Leskernick and the settlement are continuously visible after fifteen minutes :

> "Brown Willy and Leskernick appear... back in fertile grassland" - Eastern Inbound 15 min stop

> "As soon as you get to the top of the hill [Brown Willy], you can see Leskernick immediately." -

Western Inbound 15 min stop

In contrast to the conclusions drawn by the work at the Tavoliere Plain, it would seem that being able to see the settlement is not an overriding importance in the Leskernick landscape. Instead, entering and exiting the bowl of hills seemed to have had a bigger effect on the investigators. It is almost as if once you are within the bowl, you are already in the enclosed territory of Leskernick and that alone already creates a feeling of being 'home'. It is important to note that the site conditions of Bodmin Moor are markedly different from those of the dry and dusty Tavoliere Plain. When undertaking the PSCA walks we were often beset by bad weather, rain and fog, along with quite boggy conditions underfoot. In contrast, the Tavoliere walks were often undertaken in high temperatures (35-40^{o}C) and dry conditions (Hamilton *et al.* 2006), which would no doubt have resulted in different distances being covered. Therefore the results of the PSCA analyses cannot be directly compared in terms of journey time or distance travelled. However, due to the body-centred nature of the methodology, comparison of the overall subjective experience of the journey is still valid.

The feeling of enclosure of the Leskernick settlement sits in contrast to the connectedness to other house circles that was revealed from the analysis of the journey time. As explained in Chapter Four, the remains of the houses themselves across the Moor are generally low-lying with only one or two courses of stone remaining, which are quite difficult to discern when viewed from a distance. The investigators may not have have noticed the other houses (in fact, no other houses are mentioned in the journey transcripts until the summit of Brown Willy is reached and the house circles outside the bowl become more obvious). There are also not very many houses which exist within the bowl of hills, with the exception of some along the Fowey valley to the south of Leskernick and some on the slopes of Catshole Tor. It is possible, if the houses were more visible, it would have made a difference to the results of the PSCA, and this is something that I will go on to explore further in Chapter Seven, within the context of the embodied GIS.

Sound and Communication

In order to further build their picture of the intra-site communications and social spaces within the settlements of the Tavoliere Plain, Hamilton and Whitehouse recorded some basic phenomena relating to sound and visual communication. This included recording the distance over which various sounds could be heard (a simatron, normal conversation, shouts) and the distances over which visual cues could be discerned (instructions using sweeping arms, facial expressions and small gestures). Over a number of field seasons they were able to compile a comprehensive account of the average distances over which visual or aural communication could comfortably be achieved and they draw comparisons between these and the various settlement sizes. Taking their work as inspiration I also collected a limited amount of this type of data in March 2013.

I decided to use two different houses as my observation points, house 35 in the southern settlement and house 16 in the western settlement. These houses were chosen as they sit within the centre of each of the settlement areas and therefore could be taken as a rough proxy for the settlement area itself. I first recorded the visual phenomena. For this, two people walked out from the houses equipped with a two-way radio and, using the same signals as are used when communicating with a total station operator over a distance (large sweeping arm gestures), attempted to communicate with a person standing in the house. The use of total station signals was deliberately chosen as all of the team were familiar with using them. They repeated this communication until the message could no longer be discerned. For both locations, the maximum distance that the signals could be accurately understood was 675m. Of course, Leskernick Hill has quite a wide range of topographic variance and therefore this is the furthest that the message they conveyed could be recognised providing there was a clear line-of-sight between the house and the people communicating. Combining this finding with the data from the PSCA walks, then, anyone approaching the settlement from the east, south or west would be able to see the settlement continuously and would be able to communicate visually with the inhabitants from up to 675m away. Anyone approaching from the north would not be able to visually communicate until they crested the top of Leskernick Hill, approximately 300m from the houses.

Where the visual communication could be considered quite a standard measure across the hill, barring any heat haze (!) or fog, the results from the sound experiments varied wildly, especially as regards to the long-distance sounds. Using the same basic methodology as with the visual communication, we took note of the distances over which we could hear and understand a normal conversation, a shout, a 20cm two-tone woodblock (Figure 59) and a metal cowbell (30cm in length, see Figure 60). The participants were also provided with two-way radios to ensure easy communication over longer distances.

Figure 59 - A two-tone woodblock

Although no bells have been discovered on Leskernick Hill or in the region, finds such as the Middle and Late Bronze Age crotal bells (a metal bell with a pebble inside it, like a rattle) from the Dowris Hoard in Co. Offaly, Ireland (Rosse 1985) and the long Bronze Age horns from all over Ireland (Coles 1963) suggest that bells or instruments may have been in use during the period. Therefore, the woodblock and cowbell are modern representations of possible sound technology that may have been available, rather than based on any direct evidence from the site or modern reconstructions.

Figure 60 - Cornelius Barton using the cowbell during fieldwork on Leskernick Hill (photograph courtesy of Guy Hunt)

From each house we walked out in the four cardinal directions, to assess the differences that the topography would have on the soundscape. The landscape-form unsurprisingly had quite an effect on the results, as did the wind direction. The results can be seen in Table 3. The average distance a normal conversation could be heard was 39m. The average distance between the houses in each of the settlements is generally less than this, therefore it would be quite easy for people to undertake conversations between the houses, but not between the two areas of the settlement. Shouts could be heard and understood on average 144m away, so even when shouting, communication between the two parts of the settlement would be hard (the closest houses in each settlement area being c. 175m apart).

Site	Direction of travel	Metres	Sound	Environmental Conditions	Limit/scale of sound
House 35	West	45	Female talking	Windy, from east	voices audible but indistinct
House 35	West	60	Female shout	Windy, from east	shouting audible but indistinct
House 35	West	140	Woodblock	Windy, from east	inaudible
House 35	West	150	Cowbell	Windy, from east	very faint
House 35	West	225	Cowbell	Windy, from east	inaudible
House 35	North	45	Female talking	Windy, from east	audible, indistinct
House 35	North	150	Female shout	Windy, from east	audible, indistinct
House 35	North	550	Woodblock	Windy, from east	inaudible
House 35	North	800	Cowbell	Windy, from east	inaudible
House 35	East	50	Female shout	Windy, from east	audible, indistinct
House 35	East	250	Female shout	Windy, from east	audible, indistinct
House 35	East	900	Woodblock	Windy, from east	inaudible
House 35	East	1100	Cowbell	Windy, from east	inaudible
House 35	South	21	Female talking	Windy, from east	audible, indistinct
House 35	South	185	Female shout	Windy, from east	audible, indistinct
House 35	South	300	Woodblock	Windy, from east	inaudible
House 35	South	325	Woodblock	Windy, from east	returned to audibility
House 35	South	950	Cowbell	Windy, from east	inaudible
House 16	South	30	Male talking	Wind from NE	voices audible but indistinct
House 16	South	90	Male Shout	Wind from NE	voices audible but indistinct
House 16	South	115	Male Shout	Wind from NE	inaudible
House 16	South	230	Woodblock	Wind from NE	inaudible
House 16	South	230	Cowbell	Wind from NE	inaudible
House 16	West	50	Male talking	Wind from NE, foggy	voices audible but indistinct
House 16	West	106	Male Shout	Wind from NE, foggy	inaudible
House 16	West	950	Woodblock	Wind from NE, foggy	faint
House 16	West	950	Cowbell	Wind from NE, foggy	faint
House 16	West	>1200	Cowbell	Wind from NE, foggy	audible
House 16	North	35	Male talking	light wind from NE	voices audible but indistinct
House 16	North	125	Male Shout	light wind from NE	audible, indistinct
House 16	North	675	Woodblock	light wind from NE	inaudible
House 16	North	900	Cowbell	light wind from NE	inaudible
House 16	East	50	Male talking	light wind from NE	voices audible but indistinct
House 16	East	100	Male Shout	light wind from NE	audible, indistinct
House 16	East	450	Woodblock	light wind from NE	inaudible
House 16	East	450	Cowbell	light wind from NE	inaudible

Table 3 - The results from the sound experiments

The distances that shouts and conversations could be heard was relatively the same from house 35 and from house 16, with the cardinal directions not having much effect. The distance that the woodblock and cowbell could be heard, however, varied a lot between houses and the direction walked made a big difference. There was a marked difference in the audibility of the cowbell when walking east or west from the houses then when walking north or south. When walking north or south the greatest distance the cowbell could be heard was 900m. However, when walking east or west from the houses this increased to over 1.3km. Clearly, we were not creating an accurate acoustic map of the hill, and it is likely that most of the difference can be explained by the topography. When walking north out of house 35, the bulk of Leskernick Hill obscured the sound – resulting in some interesting acoustic effects. The cowbell (and the woodblock) both sounded as if they were coming from an easterly direction; it was almost as if the sound was bending around the rise of Leskernick Hill. The east and west of Leskernick Hill is flanked by valleys, so when we walked out from the houses sounding the cowbell and woodblock, the sound was clear until the walker entered the valley and then it became almost inaudible (in one walk the woodblock could no longer be heard). However, once the walkers emerged from the valleys the sound came back completely clearly – and in the case of the western walk could be heard almost halfway to Brown Willy.

As Hamilton and Whitehouse rightly claim and as we experienced on the Hill, the perception of the maximum visibility and distances over which sounds or gestures can be understood will vary depending on the conditions, and therefore, to collect a comprehensive dataset the data collection would have to take place on multiple different occasions in multiple different conditions (2006, p.48). My results, therefore, should only be taken as an indication of the situation on Leskernick Hill, and further fieldwork is needed to refine the results. However, even my limited experiments do raise some interesting observations on the layout of the settlement.

The first of these is that the ritual area (the stone row and circles) is within visual communication of the houses in the southern settlement, but human voices, whether talking or shouting, would not have carried to the houses. However, if wooden or metal instruments were being used during any rituals then their sounds would likely have reached both of the settlements. The valleys on both sides of the Hill are also within visual communication of the settlement, at least for wide, sweeping gestures. This means that if these valleys were being used for tin extraction, rush-cutting or water collection, it would be very easy for people in the settlement to communicate with those in the valleys and vice versa. The sound reflection effect of the valleys is also very interesting – with the sound being much clearer when coming from the valley sides –

allowing for quite easy communication over long distances on the valley sides. This means that even in foggy conditions, animals (with bells on) could be easily monitored from the settlement, even if they are grazing on the lower slopes of Brown Willy to the west or on Hendra Downs to the east. The use of the voice, horns and bells features widely in ethnographic studies of transhumance societies. For example, the shepherdesses of the Scandinavian highlands use a complex set of vocal sounds to herd their cattle, to communicate with other humans when in distress and also to chase away predators (Ivarsdotter 2004). The cowbell and horns were also used to chase away evil spirits before taking the cattle to the grazing areas, emphasising the ritualistic nature of such aural communication (Ivarsdotter 2004, p.148).

A Break In Presence?

As I undertook more of the PSCA walks and the sound experiments, my familiarity with the landscape naturally increased, along with a greater knowledge of the names of the various hills and features. Having personally walked all of the transects, when I now look at a paper map of Leskernick or at the GIS database I can easily 'transport' myself there and put myself back into the landscape. This feeling took some time to develop and it highlights the importance of visiting and revisiting the landscape at different times and seasons. As an example, when I first visited Leskernick Hill, beyond that which I had gleaned from the literature and had seen from aerial photographs, I did not have a real idea of what it was going to be like. During my first walk across the vast tin streaming areas, I did not recognise them for what they were and assumed they were river valleys, clearly modified in someway, but for what purpose? The PSCA required me to explore the landscape in a completely different way. It forced me to stop at these features, examine them closely and research what they were. This initial lack of familiarity with the landscape is obvious from some of the earlier transcripts:

> “you might find that other [mark?] is the actual cairn, and what we were calling a cairn before is a propped stone” - Northern Inbound 20 min stop

> SE: “just as we come over the side of this hill, we've got what is probably the Beacon in front of us, it must be mustn’t it?” GH: “yeah, I guess so, yeah it would make sense” - Northern Inbound

20 min stop

“there have been lots of rivers to deal with [these were actually tin streaming areas]” - Western Outbound 15 min stop

“in terms of views, we're stuck down in the middle of this cutting [the major tin stream on the north of Buttern Hill], so its pretty impossible to see anything” - Northern Inbound 30 min stop

Throughout some of the early PSCA walks, the tin streams were being mis-identified, leading to a confusion as to what was a river, a stream or modified workings. This was also true of the other types of tin-streaming works (such as leats and adits). On first glance, this would appear not be too much of a problem, as when analysing the PSCA walks it is normally obvious which feature the investigator is referring to. However, the PSCA walks are not just recording the topographic features (this could after all be done more easily with a map), they are recording the investigators' own *cognitive, affective, perceptual and corporeal reactions* to these features. It is possible, then, to think about this in terms of Breaks In Presence (BiPs, see Chapter Three). My initial 'normal' reaction to the tin streams as I encountered them in the landscape was that they were river valleys, in some way culturally modified. But as soon as I did further research and found they were tin streams I experienced a BiP, my understanding of and immersion in that real landscape (my feeling of presence) was shaken. Suddenly the way that I looked upon the tin streaming features in the landscape was completely different. Now when I walk to the bottom of the streamworks I perceive them completely differently: instead of seeing them as slightly culturally modified but mainly natural features, I see them as almost entirely culturally created workings that have a long human history. My entire emotional reaction to those features profoundly changed. My body is still affected corporeally by them in the same way (it is still hard work climbing out of some of them), but I now understand the way they affect my body is a result of the process of industrialisation and can now relate that reaction to what it must have been like to walk down into and work in these tin streams.

This then, of course, changed the way that I thought about the past landscape as well. By going through the act of recording the tin streams, it made me realise in a visceral, corporeal way how close they were to the settlement and how important they are in the landscape as a whole, just ten minutes walk from the centre of the site either east or west brings you to a tin stream. It is very easy to look at Bronze Age Bodmin Moor as a collection of ritual monuments and house platforms, mainly because the tin-streams seem such a modern intrusion, yet if, as seems likely, they were being exploited, these streaming areas would have been a major part of the Bronze Age landscape as well. The depth of the tin ground has remained virtually the same since the Bronze Age. Therefore, in order for the Bronze Age tinners to get to the tin they would had to have excavated to the same depth as the post-medieval tinworkers. The workings may not have been on quite the same scale in terms of length, but there would have been deep holes/trenches across the landscape.

It is interesting to compare my reaction to the tin streams with that of the *Stone Worlds* team. Much is made of the 'Roughtor effect', and Chris Tilley placed a great deal of importance to it:

> “Chris had discovered that, at a particular point along the prehistoric stone row ... at the moment of crossing a large depression that was probably filled with water during the Bronze Age, Rough Tor suddenly came into view from behind the ridge. For Chris, the effect was startling; it reverberated with ethnographic associations having to do with transition and the ritual purification of the body passing through a watery threshold” (Bender *et al.* 2007, p.290).

As a type of initiation rite in the project, the supervisors would lead new project members along the stone row, crossing the watery depression, to reinforce the “symbolic transition into a mythological landscape” (Bender *et al.* 2007, p.290). “At the time the row was built, when the plain was mainly open grassland, the boggy area was perhaps a small stream marked by a tangle of tree and scrub” (2007, p.91). It is not entirely certain what their evidence for this claim is. When I visited this area, and came upon the same watery depression, I recognised it as a leat (an artificial ditch dug to bring water to tin streaming areas). The *Stone Worlds* team acknowledge that the area has been modified by tin-streaming, and even call it a leat, yet nevertheless suggest that “both the disalignment of the row up to this point, and the place at which it crosses water were, indeed, of great significance” (2007, p.91). When I walked the stone row, the 'Roughtor Effect' did not affect me in the same way, perhaps because I was not led down the row by the members of the original team and initiated into their mythology. Their phenomenological experience of the walk was entirely different from mine. Where I saw a prehistoric monument that had been bisected by post-medieval intrusions, they saw a liminal area, of great importance and reverence. This different reaction to the same feature is both the power and the curse of a phenomenological approach: there is no 'pure' or 'correct' answer to someone's personal perception of a landscape feature. As I explored in Chapter Two, one's reaction is always influenced by prior knowledge (Gibson 1986).

The reflexive nature of the PSCA fieldwork, therefore, made me look at the tin streams in a different way and hence to look at Tilley's 'Roughtor Effect' in a different way. What if the modern tin-streaming area that bisects the stone row were actually in use as a tin stream during the Bronze Age? What light does that shed on the purpose of the stone row? If the Roughtor effect occurs as one crosses the stream, then it follows that as one crossed the tin ground, Roughtor appeared over the ridge of High Moor. One could even go so far as to suggest that the stone row was reifying the transition across the *tin ground*, rather than just a 'watery area'.

As I have shown in the previous chapter, the tin deposits may well have been of importance to the inhabitants of Leskernick, and the PSCA fieldwork has demonstrated that not only were the tinning areas in visual and aural communication with the settlements, they may have also been reified by the ritual monuments as well. Leading on from this, during the PSCA walks another possible class of ritual monument quickly became obvious in the landscape. When reaching the top of the major tors, a series of seemingly naturally occurring hollows can be seen in the granite outcrops. These features have been called 'solution basins' or 'solution hollows', a number of which have been investigated by Chris Tilley (see below). As I became more familiar with the landscape and began searching for evidence for tin exploitation, I was led to question what role, if any, these features may have played in the life of the inhabitants of Leskernick Hill.

Exploring the 'Solution Hollows'

"*In Cornwall there are monuments of a very singular kind, which hitherto escaped the notice of Travellers; and, though elsewhere in Britain, doubtless, as well as here, in like situations, have never been remarked upon (as far as I can learn) by any Writer; they are Hollows, or artificial Basons, sunk into the surface of the Rocks*" (Borlase 1973, p.240 [reprint of the original text of 1769]).

The final chapter of *Stone Worlds*, almost as an afterthought, comprises a discussion of Borlase's "artificial basins". As Tilley notes in a diary entry, "I'm surprised that I have not thought about solution hollows much before [discovering some on Roughtor] or fully appreciated the power and mystery they must have held. I suppose it is because there are none in the stones at Leskernick" (Bender *et al.* 2007, p.430). Once Tilley had noticed these hollows, the survey team set out across the Moor to document the locations of any other examples. They discovered a total in excess of 160 examples on twenty of the thirty-eight principal hills (Bender *et al.* 2007, Table 19.1). The basins form naturally in the first instance, as a product of the normal weathering process. "Gradually ... a small hollow becomes progressively enlarged and deepened and as the matrix of the granite dissolves, crystals of quartz are deposited and form a glistening layer at the bottom of the basin" (Bender *et al.* 2007, p.432). These small hollows can grow to be (in some cases) 5m in diameter and 50cm deep and often have small lips or channels that lead into separate basins. They form almost exclusively on the high tors, where the granite is flat enough and without crevices or cracks to allowing them to erode evenly.

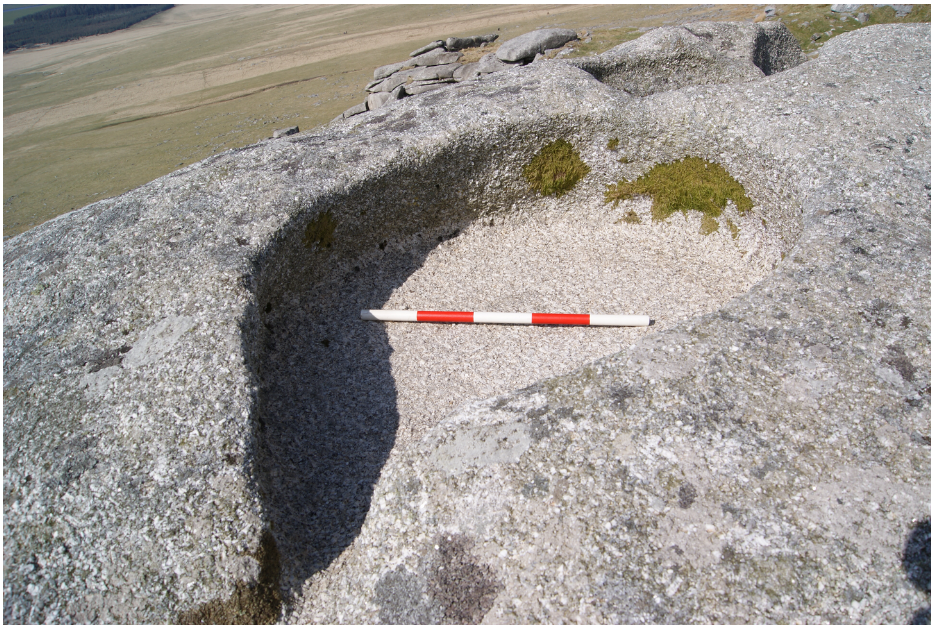


Figure 61 - A solution basin on Roughtor (1m scale bar)

The archaeological literature on these phenomena (at least in the Cornish examples) seems to be rather limited, with only Tilley and Bennett (2001), Borlase (1973) and Bender *et al. (2007)* offering any explanations as to their cultural significance. They follow Borlase's initial explanation, which is that the basins were used to collect "the purest of all water ... that which comes from the Heavens, in Snow, rain or Dew" (Borlase 1973, p.248). He explains that the basins were likely to have been used during Pagan or Druid rituals, perhaps to perform ritual cleansing or divination. He suggests the holy water of the unconnected basins "...might serve to mix their Mistletoe withall, as a general antidote; for doubtless those who would not let it touch the ground, would not mix this their Divinity (the Mistletoe), with common water" (Borlase 1973, p.257).

In order to reach his conclusions, Borlase disregards other possible uses of the rock basins, including salt collection, tin processing, altars for idols or deities or sacrifice, or for the lighting of holy fires. Having visited a number of these solution basins, the holy water answer could certainly be the case – the solution hollows are invariably filled with water during most seasons. The other suggestion is that once the water was collected in the basins, presumably it was not taken off the tors and was used *in situ*. This again is a reasonable assumption, and Borlase goes onto suggest that the basins with lips and channels may have been used to funnel the water into other containers to use the pure water in libations or ceremonies. As Tilley and Bennett conclude, “shorn of references to Druids and that the basins were carved by people, Borlase's interpretations of the potential symbolic significance and use of the solution basins are of great importance... [and seem] entirely credible” (Tilley & Bennett 2001, p.345). Tilley is happy to follow Borlase's suggestions for the use of the solution basins, and indeed goes forward with the assumption that they were used for libations. As part of the phenomenological exploration at Leskernick, he further explores the possibility by filling some of the solution basins with “white or red liquids, offering our own libations, our thanks, to the ancestors” (Bender *et al.* 2007, p.435; 2007, fig.C8c). By using red [tomato juice] and white [milk] liquids, he is presumably referencing his earlier work on the importance of colour to prehistoric people (Tilley 1996, pp.321–322) which in turn builds on the work of Turner, who suggests that red and white represent “...products of the human body whose emission, spilling or production is associated with the heightening of emotion”: with white representing mother's milk (the child-mother tie) or semen (mating between man and woman) and red representing maternal blood (the child-mother tie), bloodshed (war, feud, conflict) or the transmission of blood from generation to generation (Turner 1967, p.87). Indeed there is a legend concerning the 'Tom Thumb Rock' basins near St. Just in West Penwith, whereby the first stranger entering town at the St. Just Feast would be lavishly entertained, a kind of 'king for a day' before being taken at sunset to the Tom Thumb Rock basins and having his or her throat cut (Cooke 1996, p.229). It is unclear exactly what Tilley is attempting to represent with the red or white liquids on Leskernick, and it runs rather contrary to his previous conclusion that the basins were for collecting pure water – unless, as is possible, the addition of blood, semen or expressed mother's milk to this pure water was of ritual significance. Of course, if this were the case, filling a solution basin to the brim with white liquid would represent quite an effort on the part of the prehistoric population; but a relatively small addition of milk, for example, would be enough to turn the water cloudy.

However, I am not certain that the collection of pure water is any more convincing than the other arguments that Borlase puts forward and subsequently refutes. The water which is collected in the hollows quickly gets contaminated with the mud, moss and the debris that blows into it, and stagnant water quickly begins to grow algae (Figure 62).

Figure 62 - Solution basin on Roughtor (1m scale)

One can certainly speculate that the 'purest of water' may be desirable, yet prehistoric people had many methods for collecting water of this kind (for instance buckets, see Briggs 1987) which may (if properly curated) have actually resulted in 'purer' water than that in the solution basins which (as Tilley & Bennett 2001, p.343 admit) are often drunk from (and defecated in) by birds and insects. Perhaps Borlase's other suggestions warrant a little more attention. His first refutation is that the solution basins were used for salt manufacture, as similar hollows are used for collecting salt on the coast of Cornwall (Peacock 1969). He dismisses this because the coast is so far away from Bodmin, which is reasonable as it would be quite difficult and time-consuming to bring brine to the basins on Bodmin purely to make salt, when it would be relatively easy to bring the salt itself. He also refutes the suggestion that the basins were used to erect stone deities or obelisks, on the grounds that their surfaces are too irregular, and that they are too close together and too shallow. No idols have been found within any of the burials or contexts in the surrounding area, which adds weight to his refutation. He goes on to suggest that they may have been the sites of funerary pyres, which he dismisses for a number of reasons, namely that the complexity and arrangement of the basins themselves make no sense for laying a large fire, "...for the uses of Fire, what needed the surface of Rocks to be any more than meerly [sic] planed and leveled [sic]?"

(Borlase 1973, p.245). He also asserts that the location of the basins (high and inaccessible) is not amenable to the amount of fuel that would need to be used to tend a fire, and indeed fire may have shattered some of the thinner stones or sections of connecting basins. Tilley and Bennett, who surveyed a vast number of the basins both on Bodmin and in West Penwith, make no mention of any evidence for fire-cracking, and from my own inspections of the basins on Roughtor and Brown Willy I can confirm there appears to be no surviving evidence for cracking or discolouration due to fire. Borlase's point regarding the amount of fuel needed to be transported cannot really be sustained however, as it has been shown that the transport of large amounts of fuel in the Bronze Age was entirely possible: for instance, O'Brien has estimated that the fires used in the Bronze Age mines on Mount Gabriel in Ireland would have required the transport of 14,000 tonnes of wood fuel over only a few months (O’Brien 2012, pp.106–107). Further to this, as I will go on to show from my phenomenological investigations, the journey to the top of Brown Willy or Roughtor carrying a load is not so onerous that it would not be possible to supply the amount of fuel needed to sustain a funeral pyre.

Although it may be a little premature to fully dismiss the “fanciful arguments” (Tilley & Bennett 2001, p.344) of Borlase there is no overwhelming evidence to support them. However, the possibility that the solution basins were used for tin-processing is flatly rejected by Borlase:

> “First, these Basons are on the tops of hills, whereas the ancient workings for Tin were altogether in valleys by way of stream-work, or washing (by help of adjacent rivers) the Tin brought down from the hills by the deluge, and violent rains. These basons are generally far from water, which every one knows is of absolute necessity to promote the pulverizing any stubborn, obdurate stones, as our Tin-ores generally are. In the next place, it may be observed, that if these Basons had been much used in pounding Tin, they would be all concave at the bottom; but what is more convincing still, is, that many of the Basons are found on such high, and almost inaccessible Rocks, that people must have been very simple indeed to have made them there, when they had so weighty a substance to manufacture by their means, and must have lifted up and let down both the Tin and themselves with such inconveniency” (Borlase 1973, pp.243–244)

Leading on from my discussions in Chapters Four and Five regarding the possible extraction of tin, it is worth giving the possibility of the basins being used in tin processing a little more consideration. As with the funerary pyres, Borlase suggests that the volume of material (tin-ore, water, *etc.*) that would need to be carried to the basin sites is inconceivable, and that the inhabitants would be 'simple' to make such an effort. The PSCA walks as described above were all undertaken wearing a modern rucksack containing bottles of water and equipment (including a computer) weighing approximately 45lbs. Whilst this rucksack obviously has a modern design and is ergonomically designed to make carrying equipment easier, the short amount of time it took to walk the PSCA distances show that it would be fairly easy to walk from the tin-streaming area to Brown Willy carrying a heavy load (c. 25 minutes). The people of the Bronze Age had relatively sophisticated ways of carrying heavy loads and they may have even had a form of rucksack ('Otzi the Iceman' carried a frame made of hazel, larch boards and skins, which was probably a rucksack [Barfield 1994, p.15]) and, as previously mentioned, there is evidence for the transportation of vast amounts of fuel to the mines in Mount Gabriel, Ireland. The objection, therefore, that the amount of labour required to carry the materials to the top of the hill would be prohibitive is rather weak and unsubstantiated.

It is worth noting here that the initial crushing and separating of the ore could have taken place directly at the area of extraction (Craddock 1995, p.161). The whole community was likely to have been involved in the early sorting and processing, which may have also included women and children (Craddock 1995; Barber 2003, p.111). This initial crushing, probably by using a large pestle to smash the tinstone into smaller pieces and separate it from other materials, would have reduced the larger tinstone to cassiterite pebbles (see Figure 63).

Figure 63 - Cassiterite pebbles on a granite mortar. The green dust is from a previous crushing of malachite (copper) ore.

Once this early sorting was finished, the pebbles could have been stock-piled and transported to the solution hollows relatively easily. If, as Richard Bradley attests, metal processing was inherently tied into 'ritual' behaviour, then the realised cost of the effort required to move the materials would be negligible. Bradley, following an extensive ethnographic review, suggests that metal production, “is not always regarded as the industrial process in the terms that are familiar today” (Bradley 2005, p.23). He states that it is often attended by danger and magic, with prohibitions on who is permitted to view the work and where it can take place (Bradley 2005, p.23). In this instance, it would, in fact, make perfect sense for the 'magical' transformation from rock into tin dust to take place in an area of special significance, perhaps removed from everyday view or access, such as in a solution basin on top of an inaccessible rocky tor. Beyond this, however, the question remains as to whether or not it would actually be practical for the tin itself to be processed in the solution hollows.

Figure 64 - Stone-carved mortar from Rajahstan (Craddock 1995, fig.5.4)

Borlase intimates (1973, p.243) that there is evidence from Ethiopia for basins of this type being indeed used for metal processing, in this case, gold. Paul Craddock, in his work on early metal mining, records a series of carved mortar holes found near an open cast mine in Dariba, Rajasthan (Figure 64). These holes were approximately 50cm by 50cm and bear a remarkable resemblance to some of the solution basins on Bodmin Moor (Craddock 1995, p.160). Although the literature suggests that there is no direct evidence from either Cornish or Welsh Bronze Age sites to indicate conclusively that basins of this type were used for metal processing, it is also fair to say that there has been very little examination of their use at all, beyond the sources already cited. The one exception is a granite outcrop, recently designated a Scheduled Ancient Monument, found by the entrance to the Poldark Mine in Wendron, Cornwall. The outcrop has at least seventeen different hollows which vary in size and shape, with the largest being 22cm long by 20cm wide and 10cm deep. The scheduling designation states:

> "Using field evidence alone the precise dating of this tin ore crushing site is not possible. It would, however, fit most comfortably into the later prehistoric period when particularly rich ore recovered from the adjacent streamwork could have been economically crushed by hand."

(Heritage Gateway 2013)

Figure 65 - The mortar outcrop at Poldark mine - http://www.themodernantiquarian.com/img_fullsize/56794.jpg

Clearly, then, it is worth exploring whether this type of activity was occurring on the tors of Bodmin Moor, with the tinstone being hauled to the top of the tor, and then crushed, using the basins as a mortar.

In order to be well received during the smelt, tinstone needs to be crushed to a fine-grain sand. To investigate what residual evidence this crushing might leave on the basins, I took part in an experimental smelting weekend directed by Dr. Simon Timberlake in June 2013. During the weekend, which included processing and smelting both copper and tin, I conducted an experiment in crushing Cornish streamed cassiterite pebbles in a granite mortar. After trying out various techniques for crushing the pebbles (direct impact with a stone pestle; laying the pestle on the stones and applying pressure; and a firm grinding motion) I concluded that firmly rubbing the pebbles in a circular motion with the pestle was the most effective way to crush them to dust. This technique did not appear to leave any noticeable marks on either the pestle or the mortar, although

I did not conduct a microscopic analysis.

Figure 66 - Crushing the cassiterite pebbles

In the modern industrial process, a fine dust is usually achieved by crushing or pounding whilst in water. Water pounding is not essential to the process, but it does result in a finer grain (Craddock 1995, p.161). This is most often achieved by 'streaming' the tin, that is, putting the crushed ore in a wooden box (a 'buddle') and running water over it to wash it down a series of wooden troughs (tyes or launders) which leaves the heavier tin-sand in the top of the system (the 'heads') whilst the lighter sand is washed away toward the end of the system (the 'tails').

Figure 67 - A series of launders for washing the tin-sand

Wooden launders have been found in association with the Bronze Age copper mines of Wales (Timberlake 2001, p.187), which gives weight to the suggestion that knowledge of this procedure was also established at this time in Cornwall.

What does this mean for the solution basins on the tors of Cornwall, however? We know that a large number of tin sources are in the valleys between the hills where the solution basins are located – and this is true of both Bodmin and West Penwith (see Tilley & Bennett 2001; Bender *et al.* 2007, chap.15 for locations). I have also shown that the solution basins not only collect water, but that the labour involved in carrying water and the ore to the tops of the hills would not be overly onerous, especially if it was seen as a ritual journey. The comparanda of similar occurrences in southern India and the outcrop at Poldark Mine suggest that using granite depressions for pounding ore is not unreasonable. While conducting our sound experiments on the Hill, we also undertook some ad-hoc sound experiments on the solution hollows. The outcrops with hollows on Roughtor exhibited some extraordinary sound qualities. They seemed to act as large echo chambers – when working on one outcrop, it was possible to have a whispered conversation with someone working on another outcrop nearly 40m away. We did not manage to explore or test this phenomenon further, but the possibility of quiet communication between people working on each hollow was very surprising and would surely have added to the mystery of the hollows themselves.

By using a combination of my PSCA walks, sound analysis, experimental archaeology and comparanda, I have demonstrated the possibility that the solution hollows surrounding Leskernick Hill were used for tin-processing. There is no direct evidence for this activity, but the phenomenological fieldwork suggests that it would not be an onerous task to transport materials to the hollows. Tilley and Bennett's conclusion that the hollows may have been used for some ritual purpose may still be true, except rather than using them for ritual libations, I suggest that they were being used for the (ritualised?) processing of the tinstone into fine dust, ready for smelting. Further fieldwork is needed to confirm this hypothesis, including an accurate record of the size and shape of the hollows, or perhaps metallurgical analysis of the hollows themselves; however, as I have shown by phenomenological fieldwork alone, it is in no way as implausible as Borlase (and subsequently Tilley) suggest.

Conclusions

In this chapter I have explored a number of different practical phenomenological techniques. A body-centred approach is vital to being able to understand and discover an archaeological landscape, and in this chapter I have revealed insights about Leskernick Hill that would not have been possible or so obvious without such an embodied exploration.

To counteract the early objections to the phenomenological method (*e.g.* Brück 2005) I have concentrated on those techniques that can be reproduced, and deliberately followed a rigorous methodology. Sue Hamilton as part of the original UCL team at Leskernick Hill was an integral part of the original phenomenological investigations. Following her work on Leskernick, she took what she had learnt there and modified those techniques for use on the Tavoliere Plain. In bringing these modified techniques back to Leskernick Hill, I am using the power of reflexivity in method by demonstrating that the phenomenological approach, while initially dismissed as too subjective or 'touchy-feely'

(Hamilton *et al.* 2006), can now provide solid results that can be reproduced, mapped and analysed. This reflexivity of method is matched by the reflexivity of the results, and how my picture of the Moor changed throughout the periods of the fieldwork.

By using the PSCA walks to 'think through the landscape' (Tilley 2004), I opened up lines of enquiry that were not obvious from a less visceral experience. As evidenced by the BiP in my Real Reality experienced whilst undertaking the PSCA walks, I would not have realised the importance of the tin-working had I not literally stumbled over it, and this changed the conclusions drawn during the subsequent PSCA walks. The fieldwork undertaken on the solution hollows of Roughtor and Brown Willy revealed the real possibility that the hollows were used for processing tin. By undertaking the PSCA walks with a substantial load on my back, I demonstrated that the materials could easily have been taken to and from the hollows, with a limited amount of effort. The PSCA approach also highlighted the importance of the two parts of the journey, there and back, and how different those journeys can be and how differently they can affect one's perception of the landscape. This is in contrast to the work undertaken by the Stone Worlds team, which concentrated on the one-way views from static house doorways, and my own GIS analysis, which provides a relatively static picture of the landscape.

By applying these techniques to Leskernick Hill, it was possible to build up a picture that not only supported the GIS analysis, but also revealed the social landscape that is hard to find from GIS analysis alone. For example, although the GIS viewshed analysis shows the areas of the landscape that can be seen from a certain location, it does not tell you whether communication would be possible or not. The PSCA added the social elements to the mathematical analysis. The tin-streaming areas are visible from the settlement and are close enough for messages to have been conveyed visually by means of arm-waving; however, the southern stone circle, for instance, is just out of range for visual messages to be sent reliably. The GIS viewshed analysis shows that both of these areas are visible in a binary form (yes or no), and the PSCA then brings a dimension that was not obvious from mathematical analysis alone, but provides this information in a quantifiable form.

However, as I have also demonstrated, while undertaking the PSCA walks there were problems in recognising the other hut circles – due to the overgrown or dilapidated state of some of them. The cairns of the Moor, which would in some cases at one time have stood nearly 5m high, are now collapsed piles of stones which are quite difficult to differentiate, especially from a distance. The results from the walks may well have been different if these features had been more obvious in the landscape: the navigation marks used may have been different, and the feelings of isolation and enclosure of the Leskernick settlement may not have been quite so obvious if the houses from the other settlements had been visible or audible. All of these features are mapped in the GIS, and the views to or from them can be easily taken into account in any GIS analysis. But from a phenomenological perspective, when on the ground, these features are not so easy to see or identify, especially over long distances. However, if they were complete and visible they would almost certainly have affected the subjective responses to the landscape.

Chapters Five and Six have shown the interpretive power of the latest GIS techniques and phenomenological method respectively. I have also shown that both these approaches have their flaws and therefore should not be used in isolation. In the following chapter I take this one step further and combine both methods into one unified approach that aims to build on the work I have already undertaken and bring it together to form an embodied GIS.

By using the statistical models from the GIS that could only have been created and tested using the power of a desktop computer, I have been able to show that the houses on Leskernick Hill may have been placed to take advantage of views of both the eluvial tin-streaming areas and the northern stone circle. The PSCA walks and sound experiments, which by definition can only be undertaken within the landscape, have shown that these areas would have been in communication with the houses and that it is possible that the solution basins on the surrounding hills were used for tin-processing. I have also shown that the bowl of hills surrounding Leskernick provides a feeling of isolation, but this landscape form can also act as a dampener or amplifier for sounds, which raised questions about how the landscape may have been used in terms of pastoral activity. By combining both the GIS and the phenomenology within a single augmented reality model – I can build on and further test and explore these interpretations and, possibly, redefine the conclusions I have reached so far.

Chapter 7 - The Embodied GIS

"We don't know what it is, what it can be, what it will be, all we know is that it's cool..."
(Zax 2013)

This quotation, taken from the movie 'The Social Network', was used by MIT technology analyst David Zax to describe the new Google product, Google Glass (Google Inc. 2013a). Google Glass consists of a normal eye-glasses frame, along with a small display that sits above the right eye and feeds images and video directly to the user, overlaid on their normal vision. At present, this information is rather mundane, for example, it can let you know the current weather report, or will flash an alert if someone has sent you a message on Facebook. It is voice controlled to allow hands-free access to the interface and also includes a forward-facing camera that enables the wearer to share what they can see with the wider world. Google Glass is an example of the augmented reality technology that is currently emerging and will start to bring a prototype form of augmented reality to the general public. As Zax says, at the moment the technology is considered very 'cool' and it seems as though the applications are being led by the technology rather than vice versa. Google have created a hands-free mobile telephone, that will essentially eliminate the need to scrabble around in your pocket to retrieve your telephone, and may be the first widely-used example of always-on wearable computing. It is also likely to become a perfect vehicle for beaming advertisements directly into your field of vision, advertisements that you cannot help but see.

Despite the possible dystopic tendencies of such a device (Anthony 2013), Google are getting people used to the idea of overlaying information directly into the user's field of vision, something that is fundamental to the idea of the embodied GIS. However, the embodied GIS has potential to be much more than just a simple overlay of the latest weather report onto your field of vision (though the rain on your Google Glass might tell you just as much about the current weather as an augmented report right next to your eyeball). In Chapter Three I made some suggestions as to the concept and potential usage of the embodied GIS, and some of these may not yet be possible due to the current state of affordable computer technology, however, a large number of aspects can be created and used now. This chapter builds on the GIS and phenomenological research discussed in Chapters Five and Six, and demonstrates a way to combine the computing and analytical power of the GIS, with the landscape-based subjective analysis of phenomenology.

I will first discuss the basic building blocks of the embodied GIS, what software and hardware I used and some of the potential issues with the technology as it currently stands. I will then go on to look at the different deployment methods that I have explored. Once I have explained how the embodied GIS is created, I will document the results of a trial application in use in the field and the use of the embodied GIS to investigate the views from a number of the house doorways at Leskernick. I will also discuss some further applications of the methodology, including for use as a navigational device and also as an aid in Phenomenological Site Catchment Analysis (see Chapter Six). Finally I draw together my conclusions from the experiments and discuss possible ways to further develop the methodology.

Embodying the GIS

As I have shown, both GIS and phenomenological approaches have suggested new interpretations for the placement of houses within the Leskernick settlements. However, both of these approaches have their flaws, GIS analysis is limited to the computer laboratory and uses an approximation of the real landscape, phenomenology can only be undertaken in the field and its subjective nature creates problems in repeatability and reconstruction. If the results and techniques used could be combined, perhaps those flaws could be mitigated and the subsequent interpretations refined and built upon. The computer-based, desk-bound GIS needs to be joined with the landscape-centred embodiment of phenomenology to create the embodied GIS.

Following from my discussions of previous Mixed Reality (MR) and more specifically Augmented Reality (AR) use in archaeology (Chapter Three), my chosen workflow for the embodied GIS revolves around a portable tablet computer (Apple's iPad3), running a custom application written using the Unity3D gaming engine. As discussed in Chapter

Three, a solution could be designed using more complex and expensive equipment – for instance, see-through AR goggles or a larger differential GPS system – which would all be wired up to work with a laptop. This approach will certainly be very feasible in a less cumbersome, more realisable format within the next few years (as evidenced by Google Glass and the Vuzix [(Vuzix 2012) range of Head-Worn-Displays [HWD]) and, as discussed, the field of MR is moving forward at a great pace, so it may be even sooner. However, as I did not have access to specialised equipment, and also as a way to make the whole system more affordable, I decided to develop for an iPad. The iPad has a number of advantages: it is light enough to carry easily, with the proper case it can be made to be robust enough for use in fieldwork, the camera is of reasonable quality, and the iPad3 has a fast enough internal processor to deal with the 3D rendering in real-time. The use of a tablet as opposed to a HWD does introduce a further Break in Presence to the AR experience, which will be discussed below, but this BiP is arguably less than would be created by using a laptop and a heavy DGPS system. However as long as the BiP of the equipment is acknowledged during the AR experience then, as the technology advances, it can be rectified at a later date using a more 'immersive' setup.

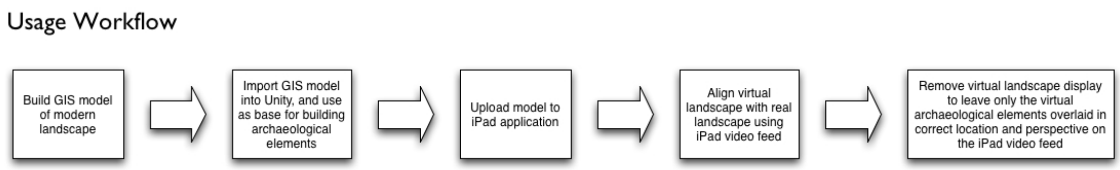


Figure 68 - The GIS/Unity Workflow

The process for creating the embodied GIS is similar to that laid out in Chapter Three, when I demonstrated the Fort AR application. It is first necessary to create a simple virtual representation of the real world within the computer environment. This virtual world is then used as a proxy to accurately place and overlay the virtual objects onto the AR display. As can be seen in Figure 68, the workflow of the system involves a number of steps and data transformations in order to make the connection from the GIS data to the AR interface. The basic workflow moves from the 2D GIS layers within a traditional GIS program to 3D representations within a computer gaming-engine via a 3D modelling program, which can then be overlaid with the correct perspective and scale onto the live video feed from the iPad.

The first imperative, therefore, is to create a traditional GIS database of the area under study, as can be seen in Chapter Five. This can include any type of GIS data, however, in order to experience and explore the data whilst in the field, a basic Digital Elevation Model (DEM) is needed – to provide the 3D backbone of the landscape. The accuracy of the DEM has an impact on the placement of the virtual objects within the AR view, a greater DEM accuracy leads to a more accurate overlay of the virtual elements. Depending on the geometry of the GIS layers (point, line, polygon) a number of decisions need to be made about how to represent the data within the 3D environment. For example, point layers could be represented in 3D by a simple sphere. This is the normal situation within most GIS packages that allow a so-called '2.5D' view (it is not true 3D as the geometry is being simulated rather than created from actual 3D data, see Koch & Heipke 2006), such as ESRI's ArcScene or the GRASS NVIZ extension. It is also possible to choose or design a 3D model that is characteristic of the type of data being displayed – and in some cases is different dependent on different attributes in the layer itself. An example of this might be an archaeological GIS layer that holds information about different types of cairn. In order for the AR view to represent this data, it would be possible to create a 3D model for each type of cairn (kerbed, banked, *etc.*) - thereby examining the differences of cairn design when in the physical space, and the effect that different cairns may have on the surrounding landscape.

When dealing with 3D it is important to remember that vector layers (*e.g.* a point representing a house) can have scale on all three axes (length, width and height). This is vital when moving to the AR view because the 3D models can be used to obscure views or create a different perception of the environment. Therefore the shape of the model takes on a greater importance. The rotation and aspect of the model also has a bearing on its representation in 3D space, and in some analyses this rotation and aspect is vital for answering specific archaeological questions (for instance, a view from a doorway). The model is therefore not just being used as an icon or a marker (as it would be in traditional GIS with a 2.5D view – see Figure 69), instead it is being used to define the make-up and feeling of the space as the user moves through it.

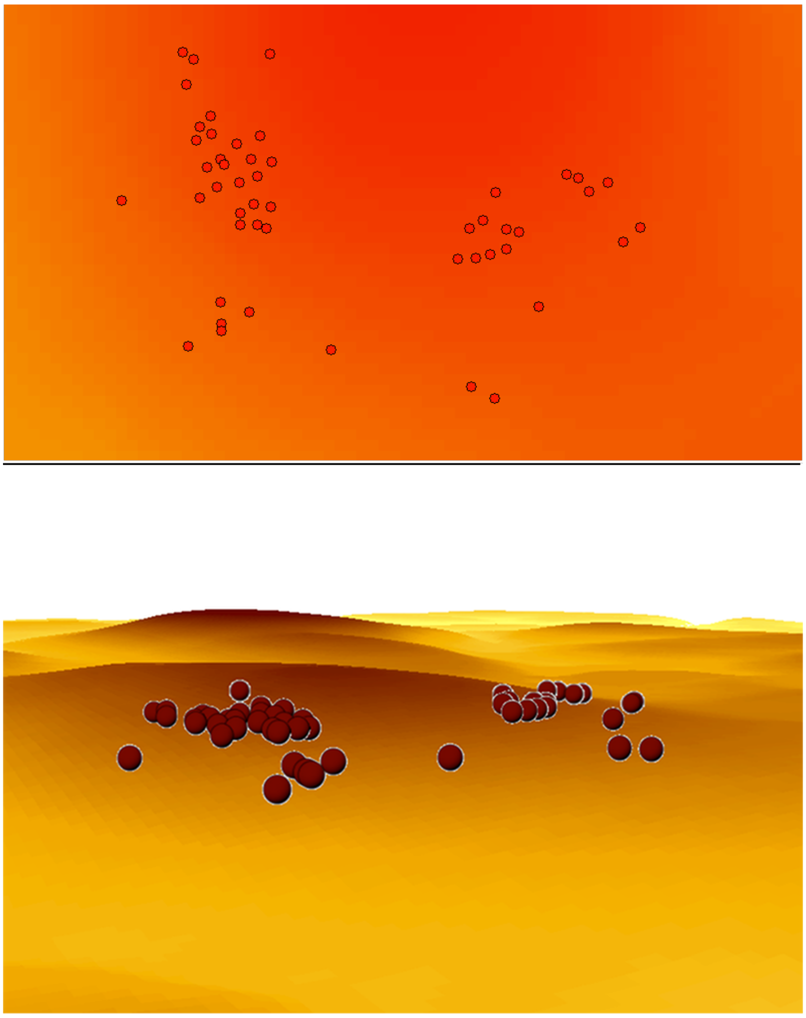


Figure 69 - The representation of point data in GIS. A 2D representation of Leskernick house locations (top) and a 2.5D representation of the same area (bottom).

It is necessary at this stage to draw on my discussions earlier of the Breaks in Presence. The 3D model does not have to be a perfect replica in every detail of a Bronze Age house if that is not the aspect of the experience that one wishes to explore. If the aspect under investigation is, for example, an examination of the crowding effect of the settlement, then just an indication of shape and mass would suffice. If, however, a detailed investigation of the colours of the thatch in relation to the surrounding landscape is of interest, then it is vital for those texturing details to be correct. Of course, as with a traditional GIS, the 'symbology' of the AR view can also be changed relatively easily during use by means of substituting different 3D models.

For GIS data with polyline geometry (for instance, an enclosure wall) the same choices need to be made. It could perhaps be enough to represent the lines in the 3D space as flat lines across the landscape – or alternatively the mass of them might be important – particularly for instance if the polylines represent the lines of settlement walls. Polygons need to be dealt with in a similar way and whereas their 2D boundaries are already defined by the GIS layer (we know their width, length and shape), the 3D shape in the z dimension (their height and profile) is not always clear and may need to be properly built up using a 3D model. It is important to reiterate here, however, that models are not needed for every single record in the GIS database – just the ones that are pertinent to the questions that are being asked. The GIS data without associated models can be represented by flat planes within the 3D space, but these will create BiPs and the BiPs will need to be recorded.

Raster data layers within the GIS can also be represented within the AR view and, as I will explore later in this chapter, the AR view is a useful way of checking the accuracy of the raster maps themselves. The raster maps can be shown as either a 3D surface (such as the DEM), as flat planes overlaid onto the real world or as a type of three-dimensional 'fog' that changes as you walk through the site. As with the previous datatypes, one has to make a decision about what aspect of the raster is important for the research questions. For instance, if the raster map is a DEM of the ancient landscape, then it is important to display it as a continuous surface, however if the raster is a map of different air pollutants then displaying it as a fog may be more appropriate.

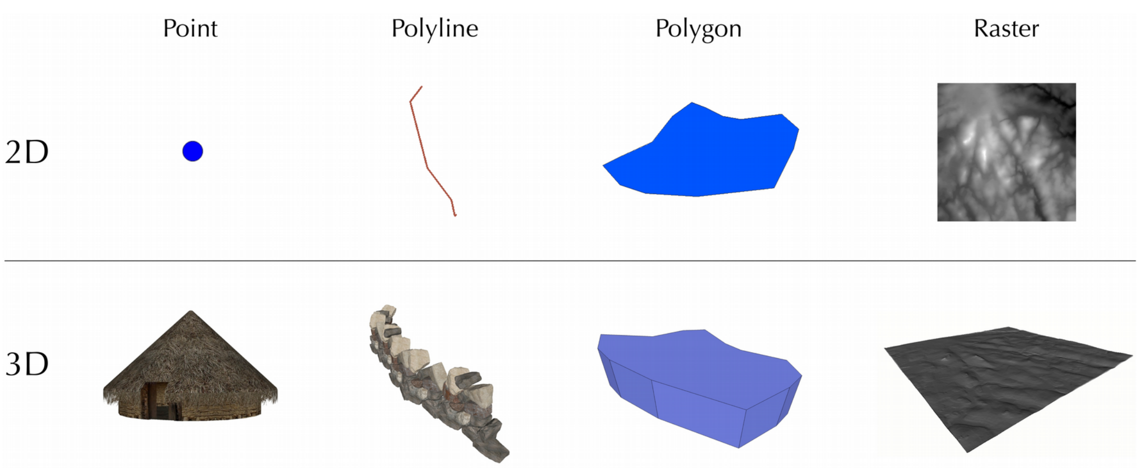


Figure 70 - Showing 2D and 3D representations of data

I followed a similar methodology to that outlined in Chapter Three, by using the Unity3D gaming engine as a basis for the iOS application. To create the 3D models for this project, I used a combination of Google Warehouse (a collection of public domain 3D models) and Google Sketchup (a simple 3D modelling tool, both available at Google Inc. 2013b) and Blender, an open source 3D modelling software (Blender 2013). After the specific models are created, they are saved in .FBX format (a common interchange format for 3D models), ready to be imported into Unity. The next important step is to import the DEM, which will act as the representation of the landscape within the AR view. The DEM is converted into a 3D model by using a special import method via Blender. The DEM is converted into a 16bit TIFF file from which a greyscale heightmap is created and a displace modifier is applied to a plane primitive to create the actual terrain (for a detailed walkthrough see Eve 2013). It should be noted here, that the necessity of using a 16bit TIFF means that some raster resolution might be lost as the conversion process does not support floating point rasters. The conversion from a floating point raster to an integer-based raster means the vertical resolution is being rounded to the nearest whole number – effectively limiting the model to a minimum of 1m vertical resolution. This problem does not have too much of an impact when dealing with height data already interpolated from contour lines as the vertical resolution is already an approximation (for example, the OS's PROFILE data) – however, it can lead to artificial terracing (a problem already well attested in normal GIS software when creating surfaces from contour data which is associated with the tiger-striping already shown in Chapter Five). It is a bigger problem when dealing with higher-resolution data (such as LiDAR data) as actual recorded data values are being lost; I will expand on these and other issues with the data import below. Once the import and displacement of the DEM is finished within Blender, the resulting 3D model is imported directly into Unity.

Unity is not a Geographic Information System and as such is not designed to deal adequately with different coordinate systems, or large areas (such as the entire British Isles). Unity3D is primarily a gaming-engine and therefore the default 'gamespace' is around 2000 game units by 2000 game units. The game units can be any nominal unit of the developer's choice and are completely dependent on the game being created. For the purposes of importing geographic data, we can assume that the game units are one metre. Therefore, in order to import a DEM at its normal resolution the gamespace needs to be created with the same number of cells as the DEM. For a 10km square DEM at a 10m x 10m resolution, the game space will need to be set up with 10,000 x 10,000 game units. The gamespace's origin is at 0,0, therefore when the data are imported they have to be relative to a 0,0 coordinate origin rather than to real-world coordinates. This simply means using a false easting and northing within the GIS software, but clearly it is also an advantage having a relatively small study area and having data in a planar/projected map projection, as the conversion will not need to take account of projections or earth curvature (as it would in a geographic projection with a datum such as WGS84, the most widely used geographical coordinate system).

Once the DEM is imported into Unity, a number of tests can be undertaken to ensure that the geographic fit is appropriate. These include placing an object within the gamespace at the location of a recognisable feature (such as the highest point of the DEM) and then comparing the in-game coordinates with the coordinates in the GIS software. If the import has been undertaken correctly, there should be no difference in the coordinates (as long as the correct calculations have been made to account for the false eastings and northings).

As briefly mentioned above, the import process as stated can lead to some loss of resolution, mainly affecting the z dimension. This is purely because the gaming engine (and 3D modelling software) are not designed to deal with complex Digital Elevation Models and the usual importing process involves interpolating the three-dimensional aspect from a greyscale heightmap. In order to create the heightmap in a format understood by most 3D software the bit depth of the original file needs to be altered. In the case of a DEM, the file (which may be a 32bit floating point TIFF file, such as the ones supplied by the Ordnance Survey) needs to be resampled into a 16bit TIFF integer-based file, which ultimately leads to a loss of information in each pixel. In the case described above the OS PROFILE data supplied as a 32bit floating point TIFF becomes a 16bit integer TIFF, meaning that any floating points are rounded to the nearest integer. This effectively reduces the vertical resolution of the DEM to 1m and any sub-1m values are rounded to the nearest metre. On a landscape scale this is perhaps not too much of a problem, especially as the PROFILE data are already interpolated from contour values – however for data which are *collected* with a sub-metre accuracy (for instance some LiDAR data) or a raster with other floating point values (such as the results of a calculation) it could potentially cause a problem. As High Dynamic Range (HDR) imaging becomes more popular, the need for 3D engines to support floating point rasters becomes all the more important as HDR images rely on a superior bit depth to be presented correctly (Munkberg *et al.* 2006). Therefore, it is not likely to be long before floating point rasters are supported in the 3D modelling software, and hence can be imported without loss of resolution into Unity. It should be noted here that any substantial increase in the resolution of the rasters when imported into the Unity environment is likely to impact on the performance of the AR experience due to the heavier load on the processor.

As outlined in Chapter Three, it is vitally important wherever possible for the embodied GIS to interact directly with the GIS data, and not just import a static model of it. If one wants to feed information back into the GIS dataset, or change the data 'on-the-fly', then any data access needs to be made either directly via a GIS server in real time or via a syncing process that checks-out the dataset from a server and then checks it back in again when syncing. This allows for any changes made to be easily synced back into the master dataset thereby ensuring that others can access the changed data without replication. In order to link the vector data to Unity, it was necessary to write a number of scripts (see Appendix One). Unity uses a combination of the Javascript and C# scripting languages, both of which have excellent libraries to deal with data manipulation. I have therefore written scripts which access the GIS data directly, reading from the attribute table of each GIS layer. For layers with point geometry, the script obtains the projected coordinates directly from the GIS data, and then applies any necessary false eastings and northings, before assigning an appropriate 3D model (either chosen for every feature in the layer, or individually assigned by the attributes) and instantiates the 3D model at the runtime of the game-engine (see *placeHuts.js* in Appendix One). The procedure is the same for polyline and polygon geometries (see *drawGISLine.cs* in Appendix One), with the difference that the 3D model for the polyline has to be a continuous model (such as a wall model that can be repeated down the lines itself) and the polygon can either have a model instantiated at its centroid or it can be 'drawn' and filled using the Unity line-drawing libraries (Figure 71).

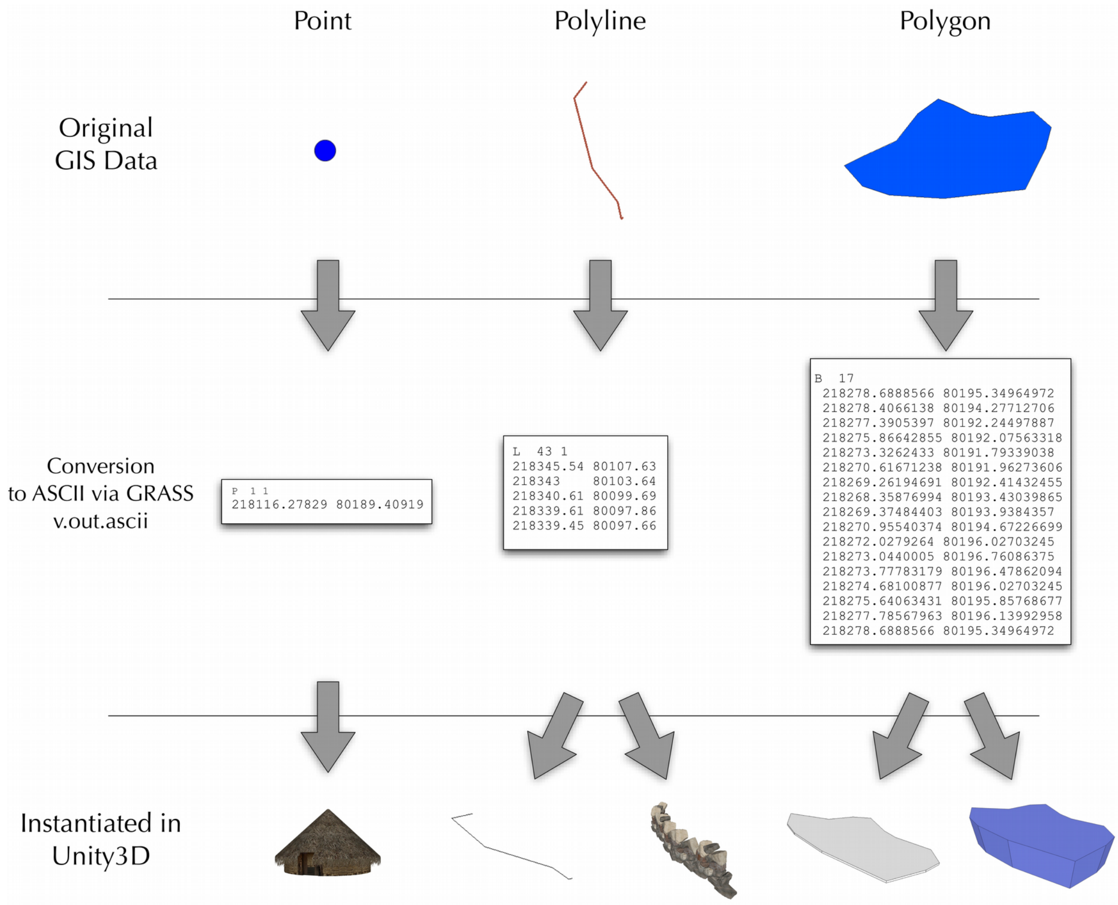


Figure 71 - Instantiating GIS data in Unity

As the embodied GIS is built from an existing GIS dataset, there should be no need for pre-processing. The data can also be accessed live, so it fulfils the need for collaborative GIS. The only exception to this case is raster data; currently there does not seem to be a way to import rasters into Unity without taking the extra step of going through Blender or some other 3D modelling program. However, the raster data can be annotated within the embodied GIS interface, and the annotation viewed in their correct geographic space within traditional GIS software.

Deploying the Embodied GIS in the field

Once the GIS data have been linked with the gaming engine software, it is possible to deploy the embodied GIS in the field. As discussed in Chapter Six, the embodied GIS builds upon the work I have already undertaken (both GIS and phenomenological analysis). One of the main aims of this approach is to address the fact that the known archaeological features are not always visible during a phenomenological investigation and therefore the interpretation of the phenomenology may change if they are present.

I will first address the way that the GIS data linked into the gaming engine environment can be viewed *in situ*. As discussed in Part One, there are a number of ways to trigger an AR experience when on site. Practically, when using a gaming-engine to manage the data, these ways are limited to two. The first is location-based, and the second is to use computer vision (CV) algorithms to 'attach' the experience to a marker in the real world that can be recognised by the AR algorithm. I advocate using a combination of the two approaches, choosing the one which best fits the individual situation.

I will now briefly reiterate the advantages and disadvantages of each approach, for the full discussion please refer to Chapter Three. As outlined above, I am using an iPad to deliver the AR experience.

Basic Navigation

At its simplest level an Augmented Reality application can be used for easy navigation around the site. As outlined in Chapter Three, this is how AR is currently used for most smartphone applications. For example, the point data for the house locations can be easily loaded into the Junaio application (Junaio 2013), which then produces flags that hover above the relevant geographic point on the iPad screen, when the application is used *in situ*.

Figure 72 - A screenshot from the Junaio application in use on Leskernick Hill. As can be seen the virtual 'flags' hover above the relevant house circles.

As can be seen in Figure 72, the flags are placed using the GPS within the smartphone or iPad and also show a small 'radar' screen that can be used to navigate to other houses on the Hill. The flags are interactive, meaning that they can be 'clicked' to pull up further information. In this case, the Junaio application links through to my personal database of the houses on the Hill, allowing me access to further information regarding the houses. This straightforward use of AR is incredibly useful for very simple navigation: it is akin to the flags used by the Stone Worlds teams to designate the locations of the houses, except the flags have potentially unlimited information attached to them and are more visible even from a long distance. This navigation application does not allow for accurate placement of other types of 3D content, and is essentially a slightly more sophisticated GPS interface than that found commonly on smartphones. To fully explore the potential of AR and the embodied GIS on the Hill, it was necessary to use more sophisticated methods.

Location-based AR

The location-based approach works using a combination of GPS coordinates, the gyroscope/accelerometer and the digital compass within the iPad. In order to utilise the location-based approach to trigger the AR content, I have written a number of custom scripts (Appendix One). The scripts take the GPS coordinates from the inbuilt GPS receiver or via manual entry and then 'place' the iPad in the corresponding location in the virtual world (Appendix One – *convertToBNG.cs*). The compass, accelerometer and gyroscope are then used to assess the direction, angle and rotation of the device (*cameraGyro.js)*. Once the position and attitude of the iPad is known, the virtual content can be overlaid onto the iPad's video feed and the virtual objects appear in the correct location and perspective relative to the user. Some advantages of this approach include the ability to walk around quite freely and easily and to be able to view the AR content from any angle. One disadvantage is that the registration of the virtual content to the real world is subject to the accuracy of the sensors themselves, and therefore may not always be correct. As explained in Chapter Three, this can often lead to inaccuracy in the position reported from the GPS chip. A further disadvantage is that a GPS signal may not always be available. The ability to manually enter the coordinates of the viewer goes some way towards mitigating these problem;, however, this then limits the mobility of the user - as the GPS coordinates will not be automatically updated and therefore the experience becomes a little more static. In the future, GPS accuracy is likely to improve, or an external GPS antenna can be used to increase the accuracy of the current GPS chip.

Marker-based AR

In contrast to location-based AR, marker-based AR uses computer vision algorithms to recognise a physical marker (such as a printed film poster, or in the case of the Roman Fort example discussed in Chapter Three, the printed base of the fort). I used the Qualcomm Vuforia extension (Qualcomm 2012) for Unity for iOS along with some custom scripts to build the AR handling functionality onto the data already imported into the gaming-engine. Vuforia is primarily a marker-based AR library.

First, a virtual representation of the chosen marker is placed within the virtual environment. The virtual marker is placed at the Unity gamespace coordinates that translate to a real geographic location (after the false eastings and northings have been calculated). The real physical marker is then placed at exactly the same coordinates and attitude in the real world. When the physical marker is viewed by the camera on the iPad in the real environment, the virtual environment is overlaid onto the iPad screen in the correct perspective and position. If the marker goes out of view of the camera, the virtual environment will no longer be displayed. A marker-based approach leads to a very high degree of accuracy for the placement of the virtual content as the algorithm can easily discern the correct angle and rotation of the marker and then transform the virtual content accordingly. However, due to the necessity of the marker being constantly in view, it limits the amount of movement through the landscape that can be undertaken. Therefore it is better suited for stationary viewpoints, or for displaying AR content on walls or tabletops (as in my Roman fort example), but as I will demonstrate below, it can also be used within a landscape. An example of this might be the replacement of an existing wall facade with a virtual model of a previous facade, or the addition of reconstructed archaeological artefacts within the remains of a prehistoric roundhouse. Marker-based AR therefore works on a much more micro-scale, allowing the finessing of an experience and the very accurate placement and representation of individual objects or features. It should be noted that as a physical marker is needed to be inserted into the real world location, it can interfere with the feeling of presence and can cause a Break in Presence (as will be discussed below).

As can be seen, neither approach is completely without flaws and both have their own advantages. I therefore have chosen to use a combination of the two – the majority of the experience is triggered using the location-based approach, which is then further augmented in specific places by use of markers in the landscape. This dual approach also accommodates a number of different scales. One of the major attributes of a Geographic Information System is the ability to view data at different scales (Oosterom & Schenkelaars 1995), and the embodied GIS should be no different. The resolution and accuracy needed for the object placement naturally increases as one views the data at a larger scale, and therefore one can use the location-based AR most of the time. However, if one is viewing interiors of buildings for instance, then the marker-based approach may be more appropriate.

Leskernick Hill Within the Embodied GIS

To show the embodied GIS working with real archaeological data I will demonstrate a number of applications based around Leskernick Hill. Once the traditional GIS data had been assembled (see Chapter Five), the data were transferred into Unity. The DTM was imported, using the method described above, by converting it to a greyscale heightmap transformed into a 3D object firstly in Blender and then imported as a plane into Unity. All of the data were imported with the units as metres, meaning that the model within Unity can be deployed at a 1:1 scale with the 'real' world. With the skeleton of the landscape in place, and the locations of the houses clearly visible within Unity, the 3D models of the houses and the stone row, circles and cairns themselves were placed, using the scripts previously described.

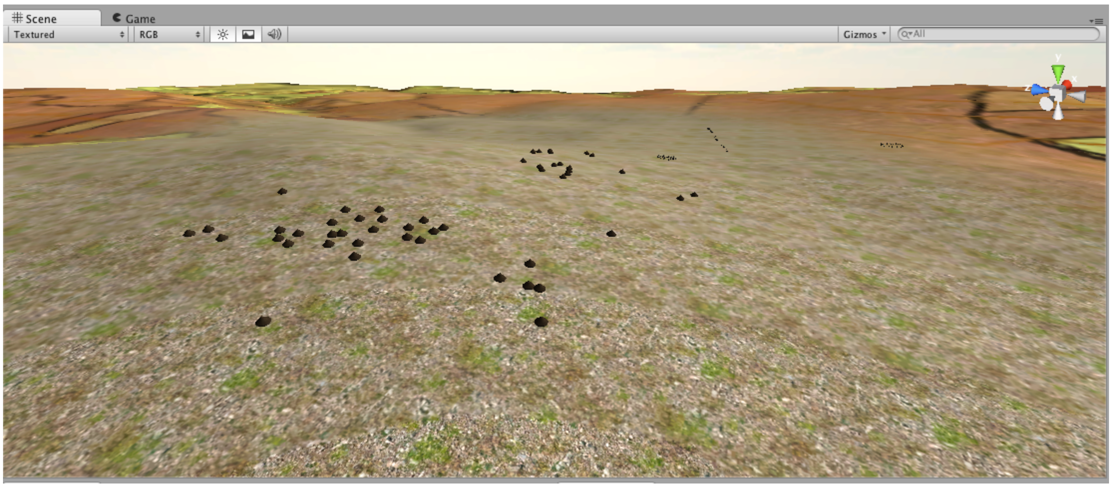


Figure 73 - The dataset in Unity3D. Showing the 3D DTM, the houses, stone row and stone circles

Experimenting with Spheres and Houses in a Location-Based AR application

The first experiment I undertook using the embodied GIS was a location-based AR experiment, to test different displays of AR data and what effect these had on the user's perception of the settlement area. To do this I set up two viewing areas, one within the western settlement (in the area of house number 50) and one within the southern settlement (within house 35). I chose these locations as they both have different perspectives on the rest of the settlement. House 50 stands slightly apart from the rest of the settlement and, when looking east from it, there is a perspective of looking from beneath the settlement up to the houses. House 35 is within a collection of other houses within quite close proximity, and I chose this location to explore the feeling of being deep within the settlement and group of houses (Figure 74).

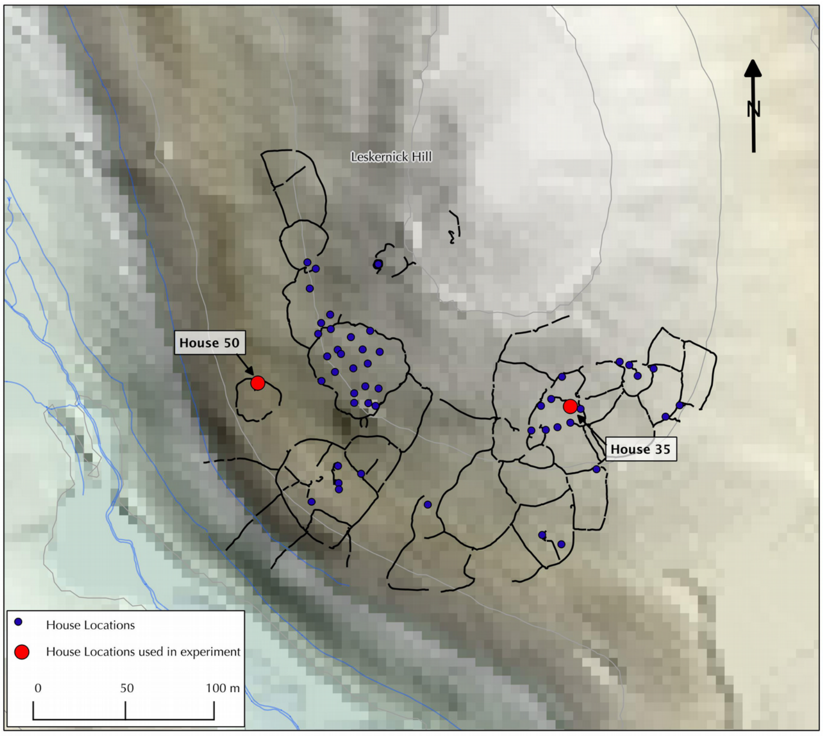


Figure 74 - The locations of houses 35 and 50

I undertook the experiment using a group of four professional archaeologists, all of whom had been working on the Hill for at least two days previously, and so had some limited familiarity with the layout of the settlement and what the remains of the Bronze Age houses look like on the ground.

The aims of the experiment were as follows:

1. To investigate the effectiveness of the iPad interface for providing a feeling of presence in the landscape.
2. To assess if the iPad interface aids in identifying the location, size and shape of the Bronze Age houses.

Setting up the experiment

In order to do this I used the location-based setup on the iPad.

Figure 75 - A screenshot taken from the iPad of the application in use at house 50. The labels for the buttons have been added for clarity.

As can be seen from Figure 75, the interface is rather rudimentary. However, the experiment was not designed to test the design of the user interface. The location of the iPad can be set either by the inbuilt GPS chip, or it can be added or adjusted manually. I undertook some initial field trials, checking the inbuilt GPS result of the iPad along with a Garmin Etrex handheld GPS receiver. The iPad's inbuilt chip returned coordinates that on average had a difference of approximately +-15m from the Garmin. As explained previously in this chapter, GPS accuracy is important for the accurate placement of the virtual content, therefore to counteract this shift I used an external GPS device connected via Bluetooth to the iPad (the GNS 5870 MFI model). The addition of this external GPS device supplied the iPad with coordinates that were much more consistent with the Garmin handheld device. The GNS 5870 (and the Garmin) still only have an accuracy of approximately +-5m, but currently this is the best that is available without resorting to a fully integrated DGPS system (none of which can currently feed coordinates directly to an iPad). The application interface also allows for the manual input of coordinates, therefore for these tests I manually input the coordinates for the centre of each house circle and we undertook the experiments standing at the centre of the houses.

The initial field trials also revealed that the combination of the inbuilt compass and accelerometer was not accurate enough to place the virtual content; there was a discrepancy of approximately 15-20 degrees when compared with a manual compass. This was overcome by utilising an initial calibration phase for the application. When the application is loaded and it has received the coordinates (either via the GPS or manual input), the Digital Elevation Model is displayed in the position calculated using the iPad's compass, it is then possible to slightly rotate the virtual content on the screen until it aligns with the real landscape as viewed through the iPad's screen. As can be seen in Figure 76, there is only a slight shift in the compass and accelerometer values, but it does have an impact on the AR view.

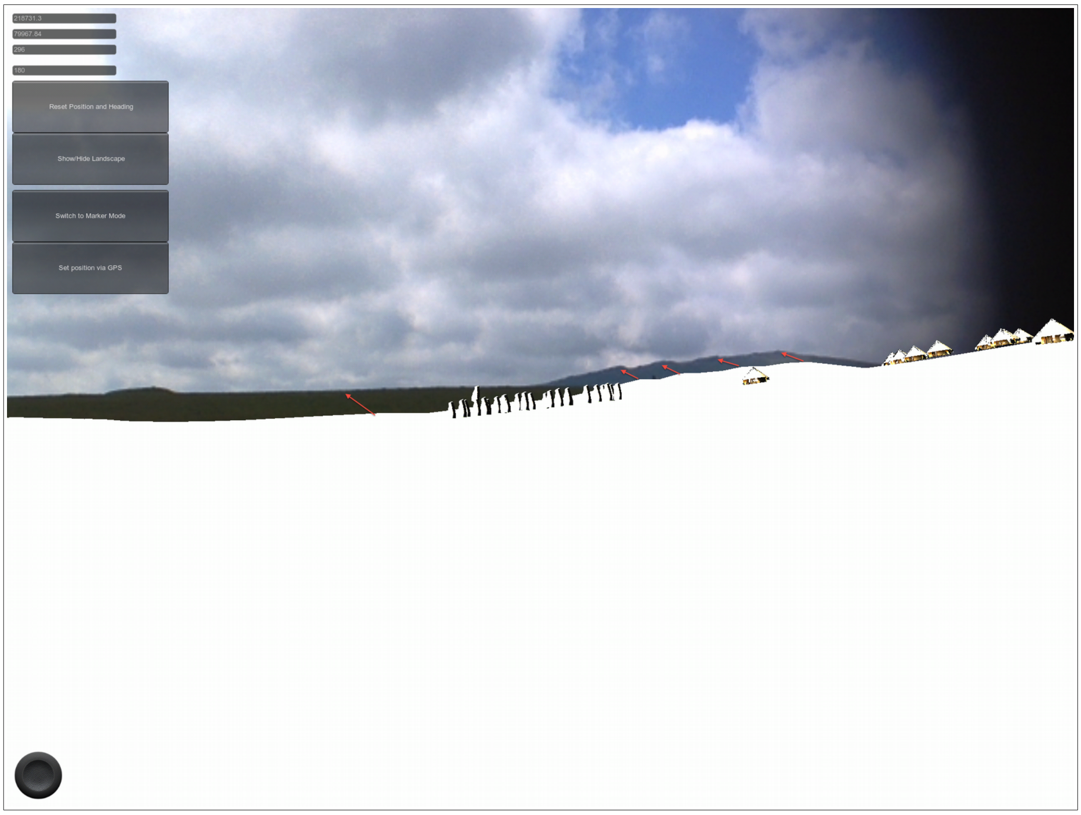


Figure 76 - Screenshot from iPad application, showing the slight discrepancy (red arrows) between the DEM and the landscape. This is remedied by sliding a finger across the touchscreen to move the virtual content until it aligns with the real landscape

Once the virtual and actual landscapes are aligned, the calibration DEM can be turned off and only the required virtual content displayed (Figure 77).

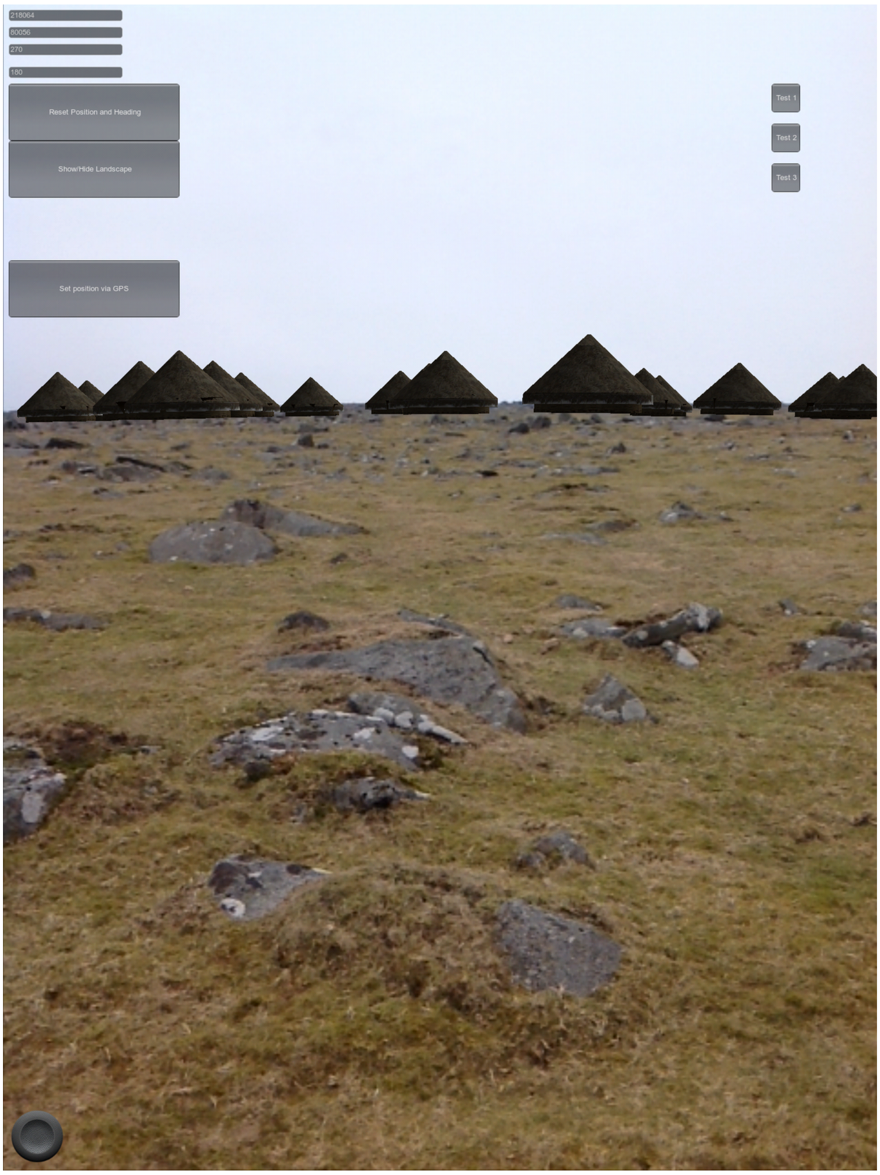


Figure 77 - Screenshot from iPad application, showing the virtual content displayed overlaid on the real landscape once the calibration phase has been completed

The Experiment Parameters

None of the participants were briefed at the beginning on the nature or purpose of the experiment. The experiment took the form of three separate tests, during which the participants were asked to identify the number of houses that they could see, while looking through the iPad screen. They were not allowed to move the screen, and had to base their opinion on the number of houses they could see by just looking at the screen, and were not allowed to look around the side of the screen. They were also asked how many houses they thought they could see *without* looking through the iPad. In order to constrain their field of view when not looking through the iPad, they were told to only count the houses they could see without moving their eyes, and to try to avoid counting the houses in their peripheral vision.

Test 1 was undertaken without any AR content being displayed at all, and they were asked to just look at the landscape through the screen. Test 2 was taken from the same position, but this time each of the house locations was augmented with a single white sphere. In Test 3 the house locations were augmented using a fully rendered Bronze Age house model. The tests were run in the following order: 1,2,3,2,3.

Results

The average number of houses seen in each test (mean from four participants) is recorded in Table 4.

Test	House 50	House 35
No iPad	3	4
1	2	2
2	2	3
3	14	3
2	2	3
3	14	3

Table 4 - Showing the results of the location based experiment

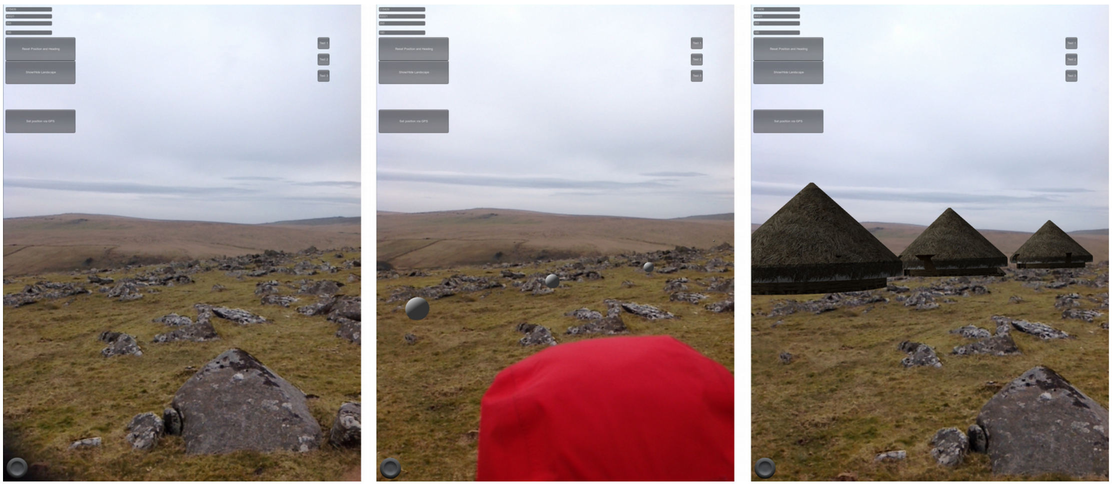


Figure 78 - Screenshots from the iPad application in House 35 showing no AR content (Test 1, left), the spheres (Test 2, middle) and the houses (Test 3, right)

The experiment revealed a number of interesting results. In both cases, the number of houses able to be discerned when looking through the iPad (without any AR mediation) is less than the number of houses that can be seen without the iPad. This is not wholly unexpected as the resolution of the iPad screen is clearly not as high as when looking with the naked eye. It does however, flag up the issue that at the very basic level any type of mediation through an electronic device is likely to have an effect on what can be perceived (see Mann 1998) and therefore even though the Augmented Reality interface should be augmenting the view, due to the necessity to look through a screen it is also diminishing some areas of perception.

Figure 79 - Screenshots from iPad application in House 50 showing the spheres (Test 2, left) and the houses (Test 3, right)

The second important observation is that in the case of House 50, the spheres made very little difference to the number of houses that could be perceived. The participants were not told that the spheres were being placed in the position of the houses, and according to the associated comments, most participants found them more confusing then helpful. The houses that can be seen from House 50 (Figure 79) are all on the skyline of Leskernick Hill. Due to the large quantities of clitter on the western side of the hill, it is often difficult to discern the houses until you are walking almost on top of them, and it is especially difficult to discern them when you are looking up from beneath (Figure 80). There are actually seventeen houses that should be in view from House 50, and the participants only identified on average three (the most anyone identified without the AR interface was five). Even with the prompts of the spheres, the participants still could not identify more than two houses. This result echoes the observations made during the phenomenological fieldwork (Chapter Six): that it is often difficult to discern the archaeological remains on the Moor amongst the naturally occurring stones.

Figure 80 - A photograph taken from House 50, showing the area viewed during the experiment. It is almost impossible to discern individual houses against the skyline.

This number changes dramatically during test 3, when the participants were able to identify an average of fourteen houses (with one person getting the 'correct' answer of seventeen). Once the 3D models of the houses were displayed, the participants were able to simply count the houses on the screen. This does not explain, however, the range of values of identified houses (from eight to seventeen). According to the accompanying comments, this was mainly due to the screen size and also the lack of contrast between the house models (they are all of a uniform colour making it hard to differentiate between them).

In the case of House 35, the participants identified three different houses consistently, in all cases. Due to the perspective from House 35 and the clearer outlines of the house circles on the southern side of the hill, the house outlines are much more obvious on the ground. However, what is interesting from this experiment is that there were actually four houses represented on the AR view – three large houses and one much smaller house in the distance. None of the participants reported seeing this smaller house.

Discussion of Experiment

The location-based AR application of the embodied GIS has provided a perspective on the settlement that would not have been possible to investigate using either traditional GIS or phenomenological techniques alone.

The AR view which included the 3D models of the houses gave a very different impression of the number of houses that were being perceived, and as such gave the participants a perspective on the layout of the settlement impossible with the naked eye alone. The size and shape of the houses are of great importance for both a feeling of presence, but also for the actual overall understanding in terms of crowding and the feelings of enclosure. As an example, when the spheres were deployed at House 50, a number were hidden behind the rise of the hill, because when viewed through the AR interface the spheres did not have sufficient height to be able to be viewed over the hill. However, when the house models were used the top of the roofs of a number of the houses could be seen, with the rest of the house being occluded by the real landscape or by other huts. In terms of the view from House 35, the sphere of the unreported house was so small that it was occluded behind the landscape and could not be discerned. During test 3, the house model was big enough to be able to be seen, but due to the house being far away it was still very small and was clearly not noticed. In the case of House 50, the settlement on the skyline would simply not have been perceived without the mediation of the AR device.

The experiment only investigated the use of the device at two locations (houses 35 and 50), however the ability to move around the site and view it from any angle or location dynamically means that it is possible to use the AR application when undertaking any type of fieldwork on the Hill or even beyond. As can be seen from Figure 81, the AR content adds a completely different perspective on Leskernick Hill when viewed from afar.

Figure 81 - Photograph (left) taken from the top of Brown Willy looking east towards Leskernick Hill, with screenshot from iPad application (right) taken from the same location with the settlement overlaid

For example, by using the application to view Leskernick Hill from the top of Brown Willy, the addition of the virtual houses immediately brings the settlement into focus and even though the forms of the houses themselves cannot be discerned, their presence breaks up the rolling landscape creating a feeling of an inhabited landscape, just as would have been the case during the Bronze Age. The location-based AR application could be used in conjunction with the Phenomenological Site Catchment Analysis to add a further dimension to the results, especially with regard to the point when the site is continuously in view.

This part of the human experience of perspective and occlusion that we almost take for granted in our everyday lives is often overlooked or difficult to calculate within GIS models. As touched on in Chapter Five, while it is possible to artificially raise the height of the DEM in the area of the houses, it is difficult to take account of the occlusion properties of the straight sides along with the pitched roof of a house. In a similar vein, when undertaking a phenomenological experiment in the landscape (like the PSCA) it is extremely difficult to mentally visualise the shape of the houses and what they would occlude. Even if the houses were physically flagged (as in the Stone Worlds fieldwork) the flags would have suffered the same fate as the AR spheres and would have been lost behind the rise of the hill, or obscured by large stones, and the tips of the roofs of those houses would not be taken into account. As demonstrated by Figure 81, flags would not be visible from the top of Brown Willy, but the fully-built houses would have been visible as would the houses of the surrounding settlements, which may have changed the feelings of the isolation of Leskernick Hill that were reported during the PSCA walks.

Using the AR device in the field highlighted some problems that I have previously raised in this chapter and in Chapters Two and Three. The main problem reported by the participants concerned the 3D content moving in a strange way when the iPad was moved. When using the accelerometer in the location-based AR application, there is a slight delay between the iPad moving and the 3D content updating its position on the overlay of the landscape. This means that if the iPad is moved too quickly, it takes half a second for the application to make the appropriate calculations to properly overlay the content again. This caused a number of BiPs, which I will discuss below and which became distracting for the users. In addition, occasionally the house models were not overlaid in exactly the correct position and rotation – which meant that they looked “out of place”, especially if the bases of the houses were not properly aligned with the real ground surface. I will expand on these problems, and some others, during my discussion of the overall AR application later – as similar problems were experienced during the marker-based AR experiment (see below).

Using Location-Based AR to Ground-Truth GIS data

As suggested in Chapter Five, it is also possible to use the embodied GIS to aid in ground-truthing the viewshed data which I used for my pure GIS analysis. In order to test this I set up an experiment that involved standing within House 35 and overlaying the calculated viewshed from House 35 onto the embodied GIS interface. All of the areas that the viewshed calculation suggested should be visible were coloured red, and all of the areas coded 'non-visible' were displayed as yellow. It follows, therefore, that if the calculated viewshed is accurately representing the view, the embodied GIS display, when used *in situ*, should show the entire landscape as coloured red (i.e. the viewshed has correctly simulated the view I have from House 35). However, as can be seen from Figure 82, the embodied GIS view from House 35 shows several areas of yellow, indicating the real view from House 35 is slightly different from that calculated by the viewshed.

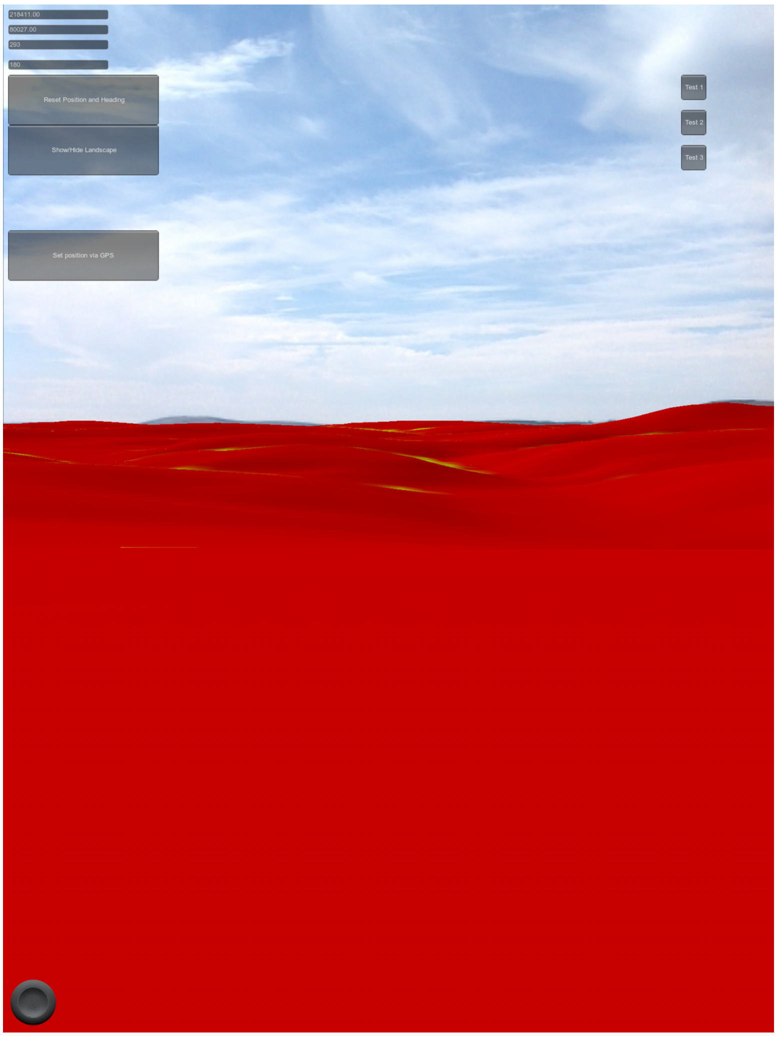


Figure 82 - Screenshot from the location-based AR view used at House 35. It shows the calculated viewshed for House 35 overlaid onto the real landscape, coloured red for the visible areas and yellow for the invisible areas

These areas are minimal, and mainly occur on the ridges of hills, but it does highlight the variable and simulated aspect of the viewshed. By developing the application further, it would be possible to highlight these areas of discrepancy in the field and feed this information back into the traditional GIS database, satisfying the two-way data exchange between the embodied GIS and the non-embodied GIS I advocated in Chapter Three. The embodied GIS ground-truthing itself is a simulation of the landscape (it uses the DEM as the backbone for overlaying the virtual content), but its dynamic nature – which allows the user to move around the landscape and investigate the discrepancies from different locations, sometimes using small movements of just a few metres - means this type of data validation and checking is possible, and possible in a way that would be very difficult to achieve using another method (for instance visiting the site and manually recording which areas of the landscape could be seen).

As I have shown, the location-based AR approach provides a broad landscape scale interface into the embodied GIS and clearly affects the user's view onto the landscape, allowing them to identify more houses, ground-truth GIS data and therefore have a different experience of the site. However, as reported during the experiments, due to problems with the accuracy of the GPS, compass and accelerometer, the virtual content was not always overlaid in exactly the right place. By utilising a marker-based approach, it is possible to more accurately 'anchor' the virtual content to a single location. I decided to explore this method further, by reexamining some of the views from the hut doorways, previously recorded by the Stone Worlds team.

(Re)Investigation of the House Doorways using a Marker-based Application

During the first season of their work on Leskernick Hill the Stone Worlds surveyors spent a large amount of their time investigating the views from the doorways of the prehistoric houses (Tilley *et al.* 2000; Bender *et al.* 2007). In order to do this, a wooden house doorway was constructed and then held up to each of the house entrances and the view through the doorway was recorded. The logistics of the exercise were clearly challenging and hilarious, “the greatest practical problem was the proximity of other huts blocking the view … This problem was resolved by people walking over to the other huts, standing on the walls and becoming the huts themselves ... it might take an hour or more to record the views from one hut doorway and everyone was rolling around with laughter at the madness of it all” (Bender *et al.* 2007, p.53). In addition to the difficulties of deciding what could and could not be seen through the existing house doorways, some of the features such as the stone circles, stone row and the cairns were so overgrown as to be impossible to see. This problem was overcome with the use of white marker flags. As well as recording the views using the wooden door frame, the team felt it was important to record the horizons, because “...for each object, distance is present” (Bender *et al.* 2007, p.332). Unfortunately, it was not possible to obtain the original records from the doorway experiments, which remain unpublished and not in a publicly accessible archive and therefore I was not able to examine their drawings in detail. Their horizon lines are published, however (Bender *et al.* 2007, fig.13:5), and therefore can be used for comparison.

I chose to re-investigate a number of different views from the doorways. The aim of this exercise was to assess whether different results would have been reached if the shape and outline of the other houses were actually present in the landscape. Where the Stone Worlds team used people, flags and a wooden doorframe, I used the 3D model of the houses, to place the viewer directly inside the house, looking out of the doorway. Within Unity I created a fully blocked out house door-frame by occluding the views around the outside of the doorframe, in contrast to the frame used by the Leskernick surveyors, which may have enabled 'peeking' around the edges of the frame. The virtual doorframe is modelled to be the same dimensions (height 1.40m, width 0.5m) as the Stone Worlds wooden doorframe when viewed in the AR view.

Figure 83 - Marker-based AR in action. The marker (the map) is held up at the side of the doorway. When it is viewed through the iPad the marker is replaced by the virtual content

As this was a static exercise, the need to move around was not quite so important and therefore I decided to experiment with a marker-based AR approach. As explained in Chapter Three, marker-based AR relies on the use of a printed marker which is recognised by the application and used as an anchor for the virtual content (Figure 83). The application then overlays the content on the iPad screen as shown in Figure 84.

Figure 84 - Screenshot from the iPad application. The augmented view from the doorway of House 16.

As long as the marker is in view of the iPad's camera, then the virtual content will remain on the screen, this allows for a limited amount of movement of the iPad, and also allows movement backwards and forwards within the house if necessary. This movement will affect the angle of view and the amount of the landscape that can be seen through the doorway, and the consequences of this will be discussed below.

Once the application and marker were set up, the participant sketched what they could see through the virtual doorway. This resulted in a series of drawings that made no distinction between virtual content and the real landscape. That is, if a virtual house were shown on the AR view, it would be added into the drawing. I felt it was necessary for the illustrators to draw what they saw on the iPad screen, rather than just taking a screenshot – to allow them to interpret what they saw and draw it accordingly. As was demonstrated in the previous experiment, participants in an AR experience are inclined to believe that what they see on the the screen is what they should be looking at and therefore, by requiring them to draw it, the virtual world and the real world are considered of the same value and recorded in the same way. A selection of the resulting drawings can be seen in Figure 85.

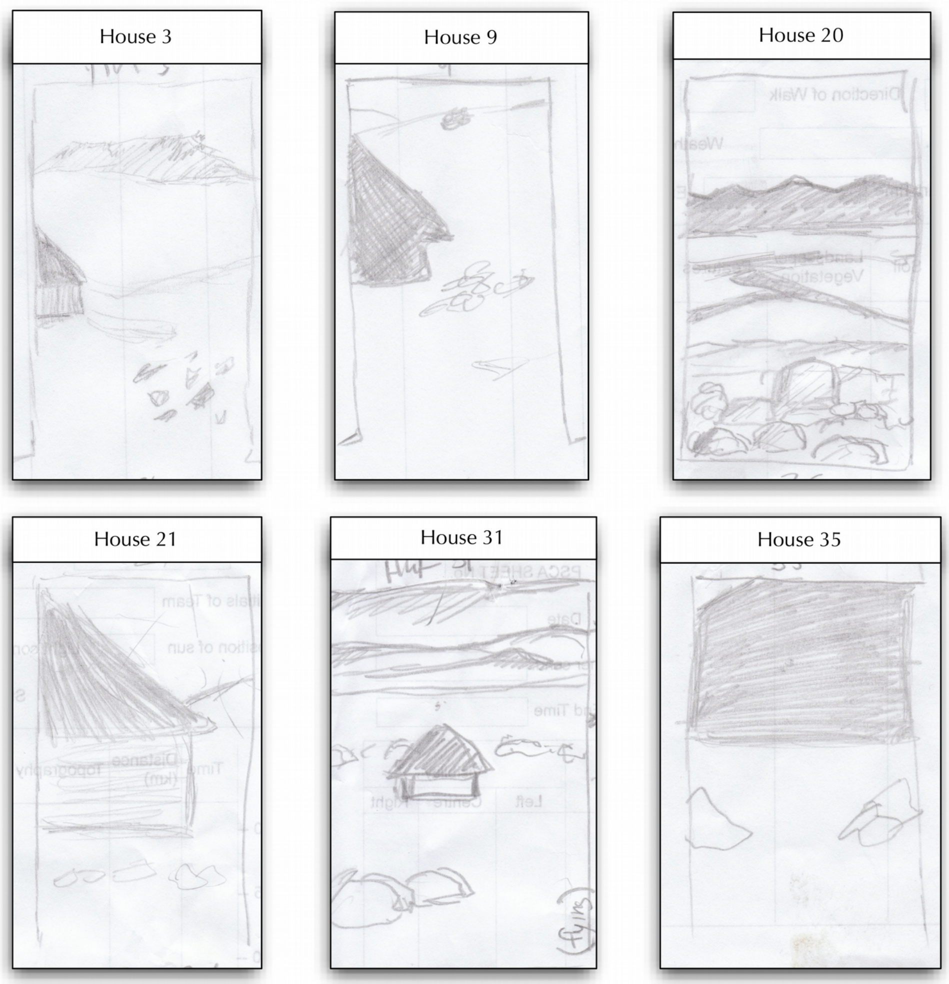


Figure 85 - A selection of AR doorway drawings

Without the original records to compare them to, it is difficult to ascertain in what way these results differ from the records drawn by the Stone Worlds team. What can certainly be said, however, is that the mass and shape of the houses makes a huge difference to the views themselves, especially of the horizons. For instance, if we look at the drawings from Houses 21 and 35, nearly all of the horizon (and indeed the rest of the landscape) is occluded by houses (recall that there is no account taken in this initial experiment of houses that may have gone out of use; therefore all houses are treated as roofed and in use). The mass of the inside of the house seems to make a big difference as well. By having an entire doorway (with overhanging thatch, *etc.*) the views from the doors are very limited. We can take House 20 as an example:

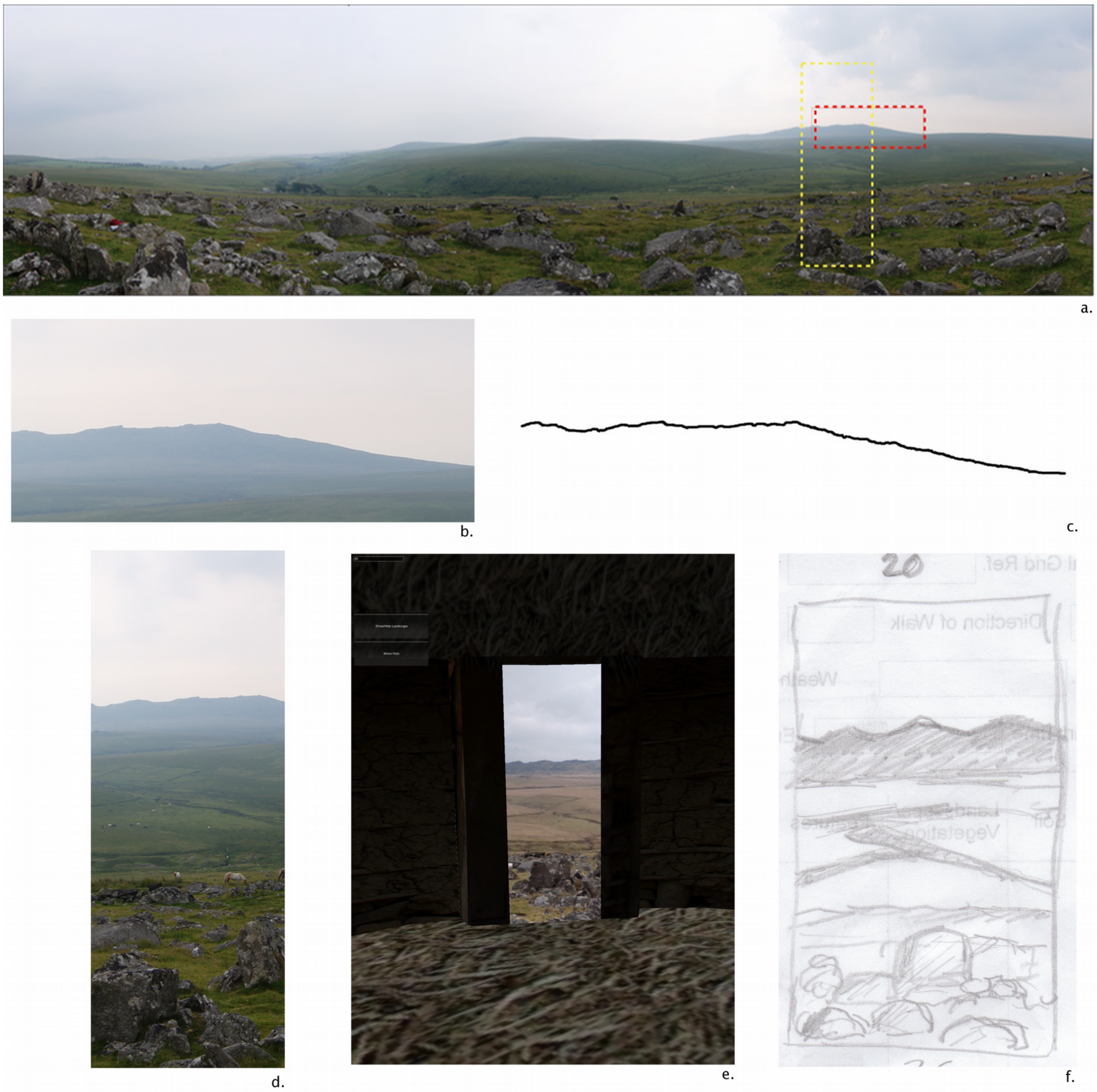


Figure 86 - Showing various views from House 20. An excerpt of the panorama of House 20, looking west (a). A section of the horizon, marked on (a) by the red line (b); the corresponding horizon as recorded previously by Bender et al. (2007)(c); an excerpt from the panorama showing the view from the AR doorway (d), marked on (a) by the yellow line; screenshot from the iPad application showing the AR doorway (e); drawing of the AR view (f).

As can be seen from Figure 86, the horizon drawn by Bender et al. (2007), represents a much wider area of landscape then can actually be seen from the doorway and shows only the distant landscape. It would appear that when drawing the horizons, the Stone Worlds team were standing at the doorway, rather than letting their view be constrained by it. The view through the doorway itself is quite limited and the width of the horizon that can be seen is much less than the horizons drawn by the Stone Worlds team. The addition of the AR doorway does not just physically limit the view, it also creates a feeling of being enclosed. The dark surround and the rendered straw floor of the 3D model focuses the view and prevents any temptation to look 'around' the side of the doorframe. One feels enclosed in the house itself and can only see as much of the real landscape as is shown on the iPad screen. Due to this being a marker-based AR experience, it was possible for the illustrators to move slightly within the virtual house, moving closer and further away from the doorway – which of course changed the view slightly – adding to the feeling that they were moving around the interior of a house. In some cases the restricted views from the doorways was quite marked (Figure 87).

Figure 87 - The AR view from House 21. Note the slight difference in perspective of the landscape between the drawing and the screenshot, the drawing was made when standing slightly closer to the doorway.

Some Problems

The marker-based approach results in a much more robust AR experience, due to the virtual content being tied to the marker, there is much less 'jumping around' of the virtual content as there is with location-based AR. However, this higher degree of accuracy of content placement means that the underlying 3D model itself also needs to be more accurate, otherwise the 'correct' content placement will not overlay directly onto the real landscape. In some instances during the drawing of the AR doorways it became clear that placement of the houses within the Unity3D application was not quite accurate. This led to some of the houses and the standing stones appearing to 'float' in mid-air (Figure 88).

Figure 88 - The AR view from House 34, with floating houses

This inaccuracy is caused by the 3D model of House 34 not being aligned properly to the virtual landscape; therefore when it is aligned to the real landscape, it is in the incorrect position. These problems can be solved quite easily by changing the model with Unity3D, but this involves recompiling the whole iPad application, requiring a connection to a computer. Although this is possible when out in the field, it is time-consuming and also there are issues with battery life and the bulkiness of the laptop. A better solution would be to allow on-site calibration of the model, by extending the iPad application to allow the movement of the virtual content (akin to the calibration stage of the location-based application).

There are also issues regarding the lack of occlusion by elements in the real world. As discussed in Chapter Three, to make the virtual content blend with the real world it is necessary for the virtual elements to be occluded by the real world itself. On a landscape level this happens within the application, meaning that the houses are occluded behind the general landscape form, allowing for glimpses of the tops of houses over the rise of slopes. However, this does not happen at a micro-level. Taking Figure 87 as an example, in the screenshot there is a large rock in the foreground that should be occluding the house seen through the doorway. However, it appears as if the house is floating above that rock. This is a problem that is extremely difficult to address with AR, especially when trying to use the application in a landscape environment (instead of a tightly-controlled computer laboratory). In order to have the real rock occluding the virtual hut, a representation of the real rock would have to be created within the application. This can be done in a number of ways, by using a depth camera to record the real environment in real-time, by importing a highly-accurate DEM (something of at least 0.25m resolution) or by using computer vision techniques (Simultaneous Localisation and Mapping [SLAM]) to create a model of the landscape by comparing different video frames. All of these options currently require much more processing power then is available from an iPad, but none are impossible. I will discuss them in more detail in the following chapter, when I go on to discuss furthering my approach. The problems with the marker-based methodology are not insurmountable, but they do lead to a number of extra Breaks in Presence that may not occur if they can be tackled adequately.

Breaks in Presence

There are a number of BiPs when using this methodology, not least the 'realistic' nature of the house outlines. From an archaeological point of view there are very few indications as to the actual full size of Bronze Age house wall heights, roof-types or even overall height (see Bender *et al.* 2007, chap.5 and 6). In addition, as I touched upon in Chapter Three, the rendering style and detail of the 3D models deployed in an AR experience are vital to the 'believability' and feeling of presence within an AR experience. Tom Frankland has undertaken a recent study on non photo-realistic rendering as a means to convey information via archaeological illustrations. His conclusions (from a survey of nearly 200 respondents) suggest that the non photo-realistic style is “is most suited to depicting interpretive reconstructions where creating aesthetic appeal or a sense of engagement are not essential” (Frankland 2012). For the mechanical nature of recording what is visible from the Leskernick doorways, the aesthetic appearance of the houses does not seem to be essential; instead it is very important that the notion of the other houses is present and that they occlude the landscape in question. Therefore, the affective BiPs which are inevitable from a non-realistic rendering of a house can be disregarded in favour of attempting to minimise the cognitive BiPs that would arise if the houses were not the correct shape or size. The same could be said of the rendering of the standing stones: as in Bender *et al.*'s use of flags to mark the locations of the stone row, the important factor in the AR experience I created is to assess whether or not the stones would be visible as opposed to what emotive response the size and shape of the stones engender in the viewer. This raises the question, however, as to the purpose of employing an AR approach to this problem, instead of simply recreating the landscape within a GIS and running a viewshed algorithm.

As touched on when discussing the experiment with location-based AR, I suggest that by using an AR approach, we manage to encapsulate both factors: the visibility of the archaeological features, *and* the different emotional response in the viewer engendered by their visibility. In the house example, being able to see a rendering of the houses in the landscape also produces a very different emotional response, by feeling the crowding of the houses, the affective nature of having to look around things, and through gaps in the housing to view the landscape. Although when using AR in this particular example, a full feeling of presence is not vital, the *nature* of the view from the doorway is also in question: Tilley and Bennett in their survey of the doorways constantly use words such as 'enclosed' or 'open' views, and these statistics could be gleaned by the use of a viewshed created from each house doorway. However, as was also obvious from overlaying the viewshed of House 35 within the embodied GIS application, the viewshed does not allow for the human micro-movement around the doorway, the shifting from side to side, the peering out the corners of the door or the glimpse through other houses to the features beyond. It also would not take account of the 3D shape of the house roof and sides – or indeed the dimensions of the doorframe itself. When analysing the view through these doorways we are attempting to get closer to what it was like for the *people* of the Bronze Age to look from their doorways at a landscape that was to a certain extent of their own design or the design of their ancestors. By cutting the human element out of the equation and delegating the analysis to a computer, the affective nature of the doorway placement is being ignored – a room with a view is not simply a binary representation of what one can or cannot see: it is the interplay between your neighbours and the houses that surround your own; the contemporaneity of these houses; the interlopers who decide to erect their house directly in your view of Roughtor; the possibly extremely complex social relations implied by these house placements; and most of all it is about how that view makes you feel about your connection to the surrounding landscape.

However, this answer needs to be tempered by an ability to recreate the parameters of this experience for others to investigate. Bringing this study back to my assertions in Chapter Two regarding Husserlian phenomenology, it is important to be able to pull the experience apart and offer other people the chance to experience the landscape, but under as many of the same conditions as my experience. Therefore, by creating the digital objects which will appear in the same place and in the same way for every user of the AR equipment I am virtually setting in stone a constituent part of the experience, thereby reducing the differences between two people's experiences and allowing the experiences to be more meaningfully compared. This is, in some ways, not very different from the methodology undertaken by the Leskernick team; each surveyor was looking at the same flags to denote the stone circles, but their interpretation of the size of those standing stones or the size and volume of the houses (marked out in their case by a human being) may well have differed from surveyor to surveyor. The affective, cognitive and corporeal experiences in AR will still quite rightly differ, as we are all individuals, but the responses will be in relation to the same inputs as opposed to each individual's notion of the size and shape of a house. The directors of the Leskernick project might raise objections to such a functionalist view of the virtual reconstructions; however, it is akin to their own reconstructions and stone-wrapping, “the work becomes anchored in the landscape, as the horizon it stands against, the colour of the earth or vegetation, the position of the sun in the sky and qualities of light all create meaning” (Tilley *et al.* 2000, p.41). In my case one's view and experience of the work is mediated through a handheld device, effectively allowing a view onto a parallel world in which the virtual art exists alongside the real world, and melds with it, becoming as much a part of the landscape as physically wrapping the stones themselves, or using flags as markers.

The embodied GIS brings further advantages to the analysis of Leskernick Hill, beyond simply replicating Bender *et al.*'s placement of the wooden doorways or marker flags. By using a GIS database to dynamically place the objects and features, their representations can be changed and updated at will, as the interpretations of the archaeology change. Their locations will remain the same, but any number of different experiments can be undertaken, to see how different shapes of houses or heights or decorations of standing stones might affect the perception of them in the landscape. Each one of these experiments can then be carefully documented and re-run with different participants using the same conditions.

Discussion

In this chapter I have explored and developed a number of different ways of using Augmented Reality to examine the landscape of Leskernick Hill. I began by introducing an application (Junaio) to aid in the navigation around the site. Leskernick Hill is difficult to navigate, mainly due to the large amount of clitter and the ruinous condition of the houses. Even this simple application greatly aided the exploration of the site and allowed the quick and easy 'flagging' of the house circles without having to physically place the flags. The virtual flags also provided extra information for each of the houses, allowing immediate access to more detailed information about the site. The navigation application draws directly from the information in the GIS database and is an easy way to represent GIS within a AR interface.

Whilst Junaio offers a navigation interface that is slightly more sophisticated than using a handheld GPS, it does not provide the versatility needed to explore the concepts I have outlined for the embodied GIS. In order to use an embodied GIS approach, a finer-grain of control is needed over the placement of the virtual content and how it interacts with the surrounding real reality landscape. The two options I explored were both built within the Unity3D application and used a location-based AR methodology and a marker-based AR methodology. These two approaches each have strengths and weaknesses, the location-based AR allowed greater versatility in terms of movement around the site, but suffered from a lack of precision with the virtual content placement, which resulted in the AR experience 'jumping around'. The marker-based approach dealt much better with the content placement, but this was necessitated by the need to only view it from one fixed location – with very little scope for movement around the site.

Both approaches needed some form of calibration stage, which reduced the immediacy of the experience. The reason for this calibration was mainly due to specifications of the hardware. The accelerometer, gyroscope and GPS unit within the iPad were not accurate enough to accurately display the virtual content within the location-based AR application. This led to a number of BiPs, which could be addressed with a more accurate system that can track the location and attitude of the iPad more precisely. The content within the marker-based application was more stable – but this stability revealed some imperfections in the placement of the content with the game engine itself. The virtual content needed to be calibrated very precisely to overlay with the landscape itself – something that would not be possible with the level of processing power of the iPad.

However, despite the shortcomings of the two approaches, I have demonstrated that they both have potential to enable an exploration of Leskernick Hill and its surrounding landscape in a new and interesting way. My experiments have shown that rather than acting as a replacement for either the GIS or phenomenological approaches, the embodied GIS instead can act as the glue between the two. By using the embodied GIS application to ground truth the output from non-embodied GIS analysis it is possible to identify areas of the GIS analysis that do not match up with the view when actually on site. This type of application has great potential for being developed further and for acting as a way to feed new information into the GIS database as a result of fieldwork. By comparing the doorway survey work of the Stone Worlds team with the views from the AR doorways I have shown that the actual 3D models of the houses being viewed *in situ* are vital for properly exploring the occluded nature and restriction of views that a full settlement would engender. They change the nature of the view in a way that would be hard to recreate if only using the imagination. Coupling this with a GIS model means it would be possible to use the attributes of each house (for instance the time span, or 'type' of house) to automatically change the models on the fly. In this way it would be possible to investigate the views of the settlement over the life of the settlement itself, perhaps first showing the early phase, and then adding new houses as they are built or taking them away as they go out of use, and being able to view the site during these different time phases. This results in an application that would allow archaeologists to explore the site dynamically in any number of different ways in any number of different time periods.

Of course, this depends on the nature of the site itself, and the possible utility of this application for other sites needs to be explored. Leskernick Hill has a large collection of quite well-defined and well-surveyed remains, ranging from houses to cairns to stone circles. The completeness of the Johnson and Rose survey has meant that a vast amount of data regarding these monuments were already available. In addition, the United Kingdom has a blanket coverage of Ordnance Survey data which provides large-scale mapping and readily available elevation data. The Stone Worlds team undertook a series of seasons of excavation and survey, recording the direction of the doorways and the dates of some of the monuments and this has all added to the wealth of data, making the collation of this information into a GIS system relatively easy (the creation of the GIS database from start to finish took approximately two months, not including any of the subsequent analysis). This level of information would not be available for every site, or it may need to be collated over a longer period of time. However, the only type of data that is vital for the creation of the embodied GIS application is a Digital Elevation Model on which to overlay and place the virtual content. As it is all linked to a 'normal' GIS system, other information can be added as and when it becomes available. The system that I have currently developed is a prototype to explore and develop my concept of the embodied GIS. The development and testing process has therefore been quite lengthy and the system is still in the testing phase. However, now that the system has been created, it would be possible to use it on any number of different sites, and indeed it would be instructive to develop the concept outside the Bronze Age landscape of Cornwall, and on different types of archaeological site (for instance a deeply-stratified urban site, or a Palaeolithic scatter site). The level of computing knowledge needed to set up the application in the first place is likely to be limited to archaeological computing specialists, however, the use of the resulting interface via the iPad is perfectly accessible to any field archaeologists accustomed to using smartphone technology (as demonstrated by the participants of my experiments, none of whom are computing experts).

In this chapter I have demonstrated methods in which to use the embodied GIS to explore Leskernick Hill and the surrounding landscape using relatively realistic reconstructions placed in areas of known archaeology. However, it would also be possible to create 'what-if' scenarios, by building a number of possible models with the GIS that could then be tested from a body-centred perspective. For instance, what if the landscape were covered with trees? What if the houses had a porch or windows? What if the tin-streaming areas were only small pits into the tin ground and not the vast open streaming areas that are visible today? What if the ground level were lowered to offset the peat build-up? What if the modern features (such as the farmhouses and field boundaries were removed)? What if there were a set of wooden semi-temporary buildings built near the tin-streams, that may have not survived in the archaeological record? What if the solution basins were being used for ritualised tin processing and had fires burning near them day and night? What would the landscape look like in varying different weather conditions, bright sun, fog, snow, heavy rain, *etc.*, and how would this affect the views to and from the settlement? The embodied GIS application would allow an exploration of all of these scenarios and the results could be fed directly back into the database and the overall site interpretation. Similar studies could be undertaken in other Bronze Age contexts, for instance, in other settlements of Bodmin Moor, the uplands of Dartmoor, or the lowlands of Wessex, to compare the appearance of the houses or features in different spaces and how the distance and landscape affects our perception of them. By undertaking the phenomenological fieldwork as described in Chapter Six while using the embodied GIS, a set of results could be systematically collected and compared, exploring these possible situations and testing hypotheses directly in the field, something that is not possible using GIS or phenomenological methods in isolation. The embodied GIS becomes a way to record certain parts of an experience, and compare those experiences across many contexts.

However, the examples and the experiments outlined in this chapter mainly concentrate on the visual aspect of the AR interface, as I have argued elsewhere in this thesis, by concentrating solely on the visual we are doing an injustice to the human experience and not creating a truly embodied GIS. I have not explored the addition or simulation of sound, smell, taste or touch. In the next chapter I will discuss how to expand the applications that I have already developed to account for the other senses and also what further directions the embodied GIS can be taken in as both the technology and the theory advances.

Part 3 – Evaluation

Chapter 8 - Breaks in Presence (BiPs)

In Part Two I used a combination of GIS and phenomenological techniques to investigate the settlement of Leskernick Hill. These 'traditional' methodologies provided a number of interesting and new interpretations of the settlement. By combining these approaches within a mixed reality environment I also explored the creation, use and possible applications of the *embodied* GIS system on Leskernick Hill. I demonstrated a successful application of the system, but it was clear that there are a number of Breaks in Presence (BiPs) that could be addressed to provide a greater feeling of presence and so a more effective system for use in the landscape. Some of these BiPs occur because the technology for the full realisation of my concept of the embodied GIS is not currently available, either because it is not affordable or else because it has not yet been developed.

I identified a number of major BiPs, including:

1. *Visual BiPs.* Some visual aspects of the embodied GIS applications did not also fit with the surroundings; specifically, there were problems with the modern landscape not properly occluding some virtual elements, and the GPS location and digital compass causing the overlay of the virtual on the actual to sometimes be mismatched. These resulted in 'jumping' virtual content or virtual content seeming to lie on top of features (such as rocks) in the modern landscape. These effects caused BiPs, because the virtual content does not seem to flow as part of the landscape and therefore becomes distracting.
2. *Temporal BiPs*. There were BiPs concerning modern aspects of the landscape: the modern farmhouse or field boundaries being present in the AR view produce a BiP because they do not fit with the Bronze Age landscape. The same was true of the deep tin-streaming channels that may not have been quite so extensive in the Bronze Age.
3. *Multi-Sensory BiPs*. The interface as described in Chapter Seven deals mainly with the visual aspects of the Mixed Reality experience. This lead to BiPs concerning the absence of the other senses. For a fuller level of presence to be

achieved the auditory, olfactory, gustatory and haptic aspects of the embodied GIS need to explored.

4. *Social BiPs*. The AR experience presented in Chapter Seven was undertaken by a single user at a time, meaning that there is a significant BiP in terms of the social aspect of the Arc of Intentionality. As only one user is experiencing the AR content at a time, it is not possible to discuss the AR content in real time or for more than one user to interact with it. Effectively the AR space is a bubble around one user and exists only for them, rather than being an augmented space that everyone can be involved in and experience. In addition there are no virtual people in the AR experience, meaning the landscape seems lifeless and empty, as opposed to populated with people moving about and engaging in their day to day lives and activities.

In this chapter I will introduce the ways that I have approached resolving these BiPs, or suggest solutions that might be possible in the future once the technology and method of Mixed Reality has progressed further.

Visual BiPs

As I concluded in Chapter Seven, both the Marker-based and the Location-based AR applications resulted in a number of BiPs from the visual affordances. These BiPs included 'jumping' virtual content, incorrect occlusion, misaligned virtual objects and the non-realistic rendering of the virtual content. I briefly suggested some solutions to these BiPs in Chapter Seven; here I will expand on these.

The problem of the virtual content 'jumping' is extremely distracting for the users and is a serious BiP, immediately reminding the user that they are viewing an augmented world and distancing them from the embodied experience. This was obvious from some of the transcripts of the experiment, with one participant exclaiming “ARGH! The balls just keep moving!”. This BiP is caused by a combination of the software and the hardware. When the iPad interface is moved quickly there is a slight latency in which the software has to query the state of the hardware (the gyroscope and accelerometer), recompute the tracking, recompute the correct position of the virtual content on the display, and finally re-render and display the virtual content. Latency is a well-known phenomenon in virtual reality studies (Jacobs *et al.* 1997; Jerald 2004; Schoonderwaldt *et al.* 2006; Jerald *et al.* 2007) and although in my application this process happens almost instantaneously, the slight delay is still enough to be noticeable by the user. This latency can be reduced by a combination of increasing processor power, which undertakes the necessary computations faster, and by improved sensors that record the position and attitude of the device faster and more accurately. The Apple iPad was not specifically designed for creating a high-end and believable AR experience, and therefore the sensors are not properly optimised. Mixed Reality systems such as the lifeClipper3 system (Torpus & Tobler 2011) use the processing power of a high-end backpack-mounted laptop, a DGPS system, a fully-immersive head-worn display and dedicated sensors to provide their software with the information needed, and thereby reduce the latency. However this is an expensive and bulky solution, as they admit "...in terms of weight and volume the equipment is not yet optimized and is generally considered to be a hindrance" (2011, p.79). By using the lifeClipper3 system on Leskernick Hill, the BiPs resulting from the latency of the iPad would certainly be reduced, but further corporeal BiPs would be introduced due to the effect of the heavy hardware on normal bodily movement. As Moore's Law (Moore 1998) assures us, technology will continue to move forwards and microprocessor components will get smaller and faster every two years, therefore we can assume that future versions of the iPad or similar tablet solutions will contain faster processors and better sensors. In addition, solutions like the lifeClipper will become smaller and more affordable. Therefore, the BiPs caused by the latency and tracking I consider to be temporary, and will be solved as the hardware technology and the software become optimised.

The visual BiPs caused by the lack of occlusion or the mis-alignment of the landscape – resulting in the virtual objects not being occluded properly – is in some way related to the problems outlined in the previous paragraph. In order to properly occlude the virtual content, the camera needs to know what it is looking at and also what the perspective relationship should be between the real world and the virtual world. As explained in Chapter Seven and demonstrated in Chapter Three I achieved this by effectively recreating the real world virtually in a gaming engine and then overlaying that virtual world back on to the real world in the AR display. However, this approach is limited in a number of ways. Firstly, the virtual world model needs to be as close as possible to the real world. Currently this is achieved by using a Digital Elevation Model, however as outlined in Chapter Five, the highest resolution DEM that covered the whole of Leskernick Hill I could acquire was only at 10m horizontal resolution. The low resolution means that it does not accurately model any feature smaller that 10m x 10m – the net result being that most of the rocks and micro-surface fluctuations are not represented. To attempt to counteract this I experimented with creating the landscape with an excerpt of LiDAR data which has a 0.5m horizontal resolution. Whereas the 0.5m resolution means that objects larger than 50cm x 50cm can be represented, the extra resolution brings with it an dramatically increased file size and the need for a much higher level of processing power to make the computations as outlined in the previous paragraph. As soon as I attempted to load the resulting 3D model into Unity3D even on my desktop PC the software crashed due to the extra computations and processing.

A solution to this problem could be to create a 3D map of the landscape on-the-fly as the user moves through the space. The real-time map would mean that the entirety of the landscape does not need to be held in memory at all times and instead is rebuilt, reacting to what the user is viewing at that time. A hardware method for achieving this is by the use of depth cameras (Jones *et al.* 2009; Wilson & Benko 2010; Izadi *et al.* 2011). A depth camera or range camera uses a technique known as range imaging to predict the location of an object in 3D space. There are a number of different techniques for achieving this, such as structured light (illuminating the scene with a specially designed light pattern whose distortion can be used to predict depth), stereo triangulation (the use of two cameras and comparing the images), time of flight (such as the technique used to collect LiDAR data) to name only three. The depth camera can be connected to a computing device (laptop or tablet) and can provide almost real-time depth information that can then be fed to specific software. The best-known example of this is used in the Microsoft Kinect camera which utilises structured light to monitor the position of a person playing a video game and allows the player to manipulate the game by using their bodily movements. The Kinect has been used by archaeologists at the University of California, San Diego as a low-cost (less than £70) 3D scanner (Boyle 2011), but as yet has not been used in an archaeological context for real-time AR applications. There is potential for the Kinect camera (or a similar device) to be connected to the iPad and then used to create a real-time depth map of the objects directly in front of the user, that depth map could then be used to occlude the virtual content on the AR display. The major problem with this approach is that depth cameras have a limited range (the Kinect for example has a range of c. 4m, see Microsoft Robotics 2013), which means that although objects less than four metres away will act as occlusion barriers, it will not detect objects beyond that, so the mid- and far-range objects may still not occlude properly. In addition, if the depth camera uses solutions such as structured light, it will not work properly in direct sunlight as the ambient light interferes with the emitted light matrix.

Almost real-time depth maps can also be made using software solutions. Much of the research in this area has arisen from the need for autonomous robotic vehicles to have a map of their surroundings, without *a priori* knowledge of the area (Leonard *et al.* 1992; Ross 1993). Simultaneous Localisation And Mapping (SLAM) algorithms utilise a number of different sensors to create a map of the robot's surroundings and continually update and augment the map as the robot moves. A similar approach can be used for Augmented Reality applications, and in some cases the sensor can be as simple as a normal camera using image-matching techniques as used in Structure from Motion (Neubert *et al.* 2007). SLAM algorithms have been used within iPad applications to produce AR experiences such as Ball Invasion AR and VuPad (13th Lab 2013; RealAReal 2013) but these are currently in their infancy. SLAM techniques offer a tantalising possibility for the future of AR but currently the algorithms are complicated, processor hungry and there remain some tracking problems (Zhou *et al.* 2008).

Temporal BiPs

A related issue encountered during the field trials of the embodied GIS was the phenomenon of distracting modern-day intrusions in the AR experience. Throughout this thesis I have argued that the key to the embodied GIS is the merging of the experience of the modern landscape with the virtual information held within a GIS. However, there are some elements of the modern landscape that can be distracting and anachronistic when using the embodied GIS. For instance, although Leskernick Hill can be considered quite wild and modern instructions are remarkably absent, there are elements in the landscape that cause a BiP when viewed in conjunction with the Bronze Age virtual content. Examples of this are the main road by Bolventor, or the modern farm buildings at the bottom of Leskernick Hill itself. Where augmented reality adds elements to real reality, diminished reality is a way of taking them away. Much as one would use a program such as Adobe's Photoshop to remove unwanted features in a photograph (Figure 89), techniques exist to remove unwanted elements within an AR application as well, known as Diminished Reality (see Chapter Two). Perhaps unsurprisingly, however, this is quite difficult to achieve as it is the equivalent of using Photoshop's 'Clone Brush' for every frame on the video feed when viewed from any angle.

Figure 89 - Looking south from House 28 with and without farm buildings

One of the main problems faced by researchers in the area of Diminished Reality is how to calculate the background image that should replace the real-world object to be diminished. Solutions include using views from multiple different cameras (Zokai *et al.* 2003), analysing stereo video feeds (the VideoOrbits planetracker, Mann & Fung 2001) or using a single camera with object tracking and image patching algorithms (Herling & Broll 2010). Of these, the most applicable to my embodied GIS setup is that proposed by Herling and Broll, which does not need any preprocessing and uses a single camera feed. The method uses contour-tracing algorithms to outline and highlight elements that should be removed from the video feed, and then synthesises the background by analysing the remaining pixels of the video frame and creating an appropriate patch. The method runs in real-time and experiments show that it creates and displays the patch one to two times faster than other methods (Herling & Broll 2010, p.212). However, whilst not computationally impossible, the method is demanding, taking up to 176 milliseconds to produce and display the patch on a 1.6Ghz Core Duo CPU laptop (2010, table 1). The iPad3 that I used for my embodied GIS experiments has a Core Duo processor running at 1Ghz and therefore Herling & Broll's solution was unfortunately at this time too computationally intensive to use. It would seem, however, that effective visual diminished reality is not too far in the future and is likely to be refined and optimised to run on the next generation of tablet computers.

As can be seen there are ways to resolve the BiPs in the visual affordances of the AR experience, but these solutions require greater processing power to cope with the increased amount of data and complexity of algorithms and improvement in the hardware and sensors used. The iPad solution that I have demonstrated is adequate for an exploration of the potential of the embodied GIS and throughout my experiments I have recorded the BiPs that have resulted from using this solution. As mixed reality technology progresses, future applications of the theory of the embodied GIS can be developed using different hardware and software that may reduce or even eliminate these BiPs completely.

Multi-Sensory BiPs

Following from the discussion of the visual BiPs, I now turn to the BiPs caused by a lack of engagement with the other senses. The visual aspects of Augmented Reality are the most easily produced as the technology used by a computer display and camera is far more advanced then for the other senses. Most people have a television or a computer in their home, but very few people have a smell dispenser or a machine that can produce different tastes on demand. However, these other senses are vital to the embodied experience and if I can see the roundhouse in the landscape, I also want to be able to touch the thatch on the roof, smell the smoke of the cooking fire, hear the chattering children and taste the cooked meat. Without those other senses the embodied experience is full of breaks in presence. As an attempt to resolve some of these BiPs I will discuss each of the other senses in turn and either show ways that I have included them in the embodied GIS or suggest ways that they may be included in the future.

Smell

"Smell, this most liminal of senses, carries a great subversive potential in its ability to violate boundaries, assault rationality, and evoke powerful emotions of disgust and attraction." (Fjellestad 2001, p.650).

Sensory psychologist Avery Gilbert has written extensively about the power of smell to augment a feeling of place and space. A particularly relevant passage from his book 'What the Nose Knows' reads:

> "The James Joyce scholar Bernard Benstock concludes that [the smell] doesn't matter as long as we have literature: "[E]ach work of fiction is posterity-proof. No captured smell specified in *Ulysses* is ever lost in the rereading or fails to register its full pungency for every new reader". Why is Professor Benstock so sure that every reader gets a noseful from the novel? This seems like wishful thinking. A reader may be able to reimagine a familiar smell, but for one he doesn't know, he's left to guess. To re-experience the smells of times gone by, one needs the *actual stuff*; without it, written references and therefore literature eventually lose their power. (Gilbert 2008, p.206).

Gilbert argues that without the real bodily experience of the smells of Bloom's gorgonzola sandwiches or the salty odour of Dublin Bay we are in fact not able to truly understand *Ulysses*, or the smell of times gone by. During the interpretation and discussion of a site, archaeologists often attempt to evoke an atmosphere by vividly describing sounds or smells, and yet it is harder for the reader to summon up the smell of something, then it is to close their eyes and see the picture of the landscape being described by the words. This may be linked, as suggested by Fjellestad, to the aesthetics we have inherited from the 19th century "...in which only two senses, vision and hearing, are considered" (2001, p.650). Yet smell has the ability to invoke intense feelings and emotions, such as disgust, attraction, fear or comfort. In some cases when used in a heritage context, smell has been deliberately toned down, because it was creating too strong a reaction. The classic example is the unveiling of the Tyrannosaurus Rex model in the Natural History Museum in London that was intended to be accompanied by the stench of rotting flesh and blood. However, the smell was considered so bad that it was more likely to put people off coming to the exhibit and therefore they chose a smell of the swamp instead (BBC 2001). Smell has also been shown to aid in the recall of certain contextual facts: using the famous smells of the Jorvik Centre in York, Aggleton and Waskett have shown that visitors to the museum remember the exhibit more clearly if they are exposed to the same smells at a later time (Aggleton & Waskett 1999).

Whilst the corporeal or chemical reaction to a stimulus such as a smell may be similar for many people, the perceptual or cognitive reaction may be very different. Of the Jorvik Centre, Kevin Walsh writes, “...the contextualising of smells from the Viking period and placement in a twentieth-century tourist attraction seems highly dubious as each person visiting the centre will have a different perception or attitude towards a smell and it is quite likely that these will be very different from those held by the people who originally produced and lived with the smells” (Walsh 1990, p.287). As I have advocated in Chapter Two, following the Husserlian premise of phenomenology means being able to pull apart and 'programme' various aspects of the experience, so making it easier to examine the constituent parts and how they differ between people. As with the other elements of the embodied GIS, as long as the smell itself is delivered in the same way for each of the users, then their conclusions from the experience can be usefully compared.

It is remiss to exclude smell from the embodied GIS, but the practicalities of experiencing different smells on a site and having those linked to a GIS system are quite difficult to overcome. Dale Air, international suppliers of a multitude of different scents and the company used by most of the major museums that incorporate smells have a vast range of different smell dispensers (Dale Air 2013). However, most of these dispensers are static and non-portable, only dispense one type of scent, or have no way of being remotely controlled or connected to a GIS. The challenge, therefore, was to find a way to create something that was portable enough to be worn by the embodied

GIS user in the field, could be programmed to release a scent when instructed by the GIS data and preferably that would allow more than one smell to be released. As part of my research I constructed a prototype device that fulfilled these needs and could be used in the field to release a scent on demand.

The "Dead Man's Nose"

Due to the need to combine a physical/mechanical action (the release of a scent) with the computer-based information (from the GIS and GPS data) it was necessary to use a microcontroller board to act as the bridge between the two mediums. The recent rise in 'maker culture' means it has become increasingly easy to create with and program microcontrollers, and they have been used to create many different gadgets, from a set of simple flashing LEDs to a self-watering gardening system that sends a message via Twitter if your plants get too dry (Whitson 2013). I used an Arduino Uno (Arduino 2013) board as the basis for what I have called the 'Dead Man's Nose' system. The Arduino boards allow a simple plug and play type approach to electronics, and reduce the need for soldering or the creation of complex circuits. Arduino boards are programmed using a simple programming language (Processing) that enables the easy creation of a WiFi network or a simple webserver.

I used a very simple set-up consisting of a mini-system blower fan, such as one found in a desktop PC, the Arduino Uno board and an Arduino Wi-Fi 'Shield' which enables Wi-Fi connectivity on the Arduino board. After connecting the fan to the board, I was able to upload a small script (Appendix One, deadMansNose.pde) to the board's system memory which provided power to the fan according to the conditions laid out in the script.

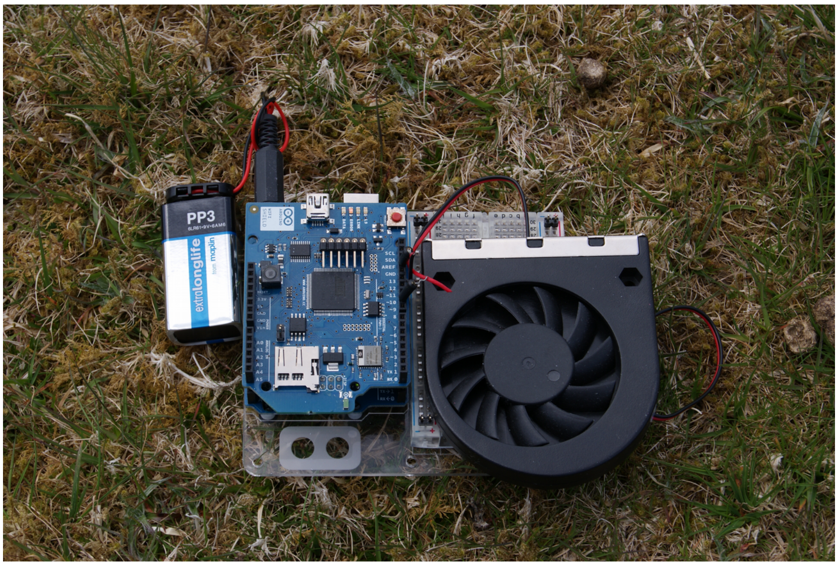


Figure 90 - The Dead Man's Nose System

As part of the testing phase, I purchased a number of different smells from Dale Air, including 'Barbeque', 'Dirty Linen' and 'Woodsmoke'. I housed the system within a simple cardboard box and attached the bottle of scent to the front of the box. When the fan starts turning it blows air across the top of the scent bottle, spreading it to the near vicinity. By placing the entire system in a bag hung around the neck it is possible to blow the smells directly to the nose.

Figure 91 - Boxed, with scent attached

Figure 92 - The bag is slung around the neck to enable the scent to be wafted upwards towards the nose

The script running on the microcontroller creates an ad-hoc webserver. The webserver translates commands sent to it via the querystring of the request URL. For example, the webserver might be accessed via the URL, *http://192.168.0.4?pin=9&power=50*. The number after the 'pin' element of the URL refers to the pin on the Arduino board that should be sent power, in this case, pin number 9, and the 'power' element refers to the analog percentage of power that should be provided to the pin, in this case 50%. It follows, then, that if the fan is connected to pin 9 on the board when the webserver receives the request the fan will begin to turn at 50% velocity. In order to be more portable, it is necessary to set the Arduino up to be able to receive requests via a Wi-Fi network, which resolves the need for any external connection wires (such as a USB connection). Therefore an ad-hoc Wi-Fi network needs to be created and the Arduino joined to it. This network can be created in a number of ways, but for testing the system on Leskernick Hill, I used my laptop as the Wi-Fi network host and joined the Arduino board to it. I then joined the iPad to the same network – which enabled the iPad to directly send messages to the Arduino's webserver and hence be able to control the fan. In order to link the fan control to the embodied GIS data, I wrote a script within the Unity game engine that sends a request to the Arduino's webserver dependent on the iPad's location (Appendix One, *smellyFan.js*).

To test the system on Leskernick Hill itself, I set up a small experiment with the premise that each roundhouse would contain its own cooking fire, and they might be cooking meat. During their work on the Tavoliere Plain, Hamilton and Whitehouse collected some limited information regarding the distance that smells could be discerned and noted that cooking meat could be smelt approximately seventeen metres away from its point of origin (Hamilton *et al.* 2006, p.52, Table 7). Using this as a proxy, I created a series of 'smellzones' across Leskernick Hill, buffering each roundhouse by 17m. To approximate the smell of cooking meat on open fires, I used Dale Air's 'Barbeque' smell. When the iPad recognises it is within one of the smellzones, it sends a message to the Arduino to begin the fan turning on a low power, and as the user gets closer to the centre of the smellzone the fan turns faster, wafting more of the smell towards the nose of the user.

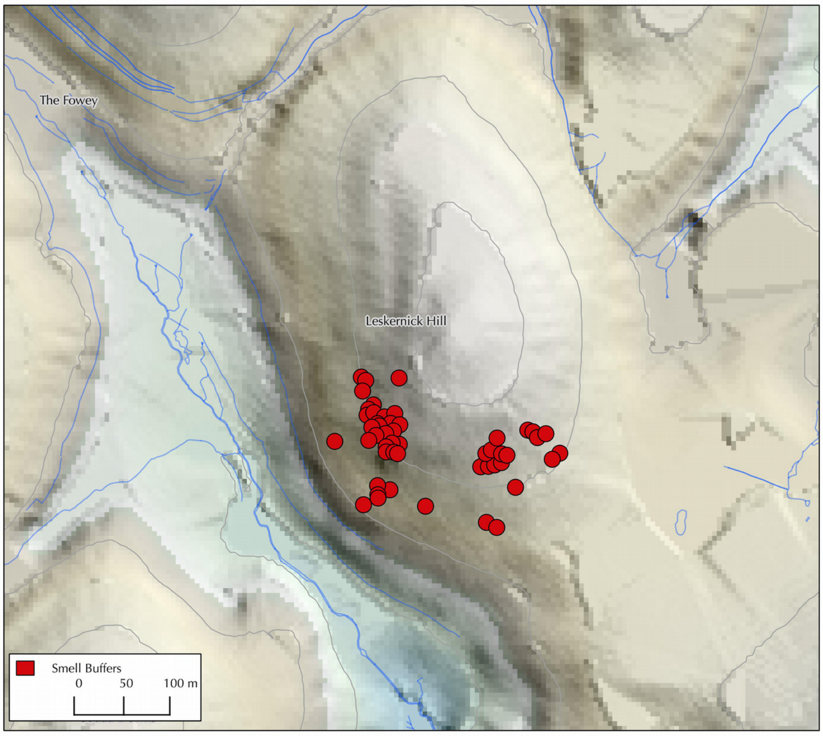


Figure 93 - The smellzones

This system was only developed as a prototype, but even the prototype performed admirably in the field. When connected to the iPad (using the Location-based AR application – see Chapter Seven), it is possible to walk around the site and when one moves closer to the roundhouses the fan begins to whir and the smell of barbequing meat is gently wafted towards the nostrils. The initial system and housing was very simple, and only allowed for one scent to be used. However, the Arduino board can easily accommodate up to five different fans, potentially allowing five different smells to be used. Obviously as more smells are added, the system becomes more bulky – but it would still be lightweight enough to be carried easily in a bag around the neck. BiPs are necessarily introduced due to the need to wear the device around the neck and also because the smell is always emanating from below the nose, rather than being wafted on the wind from its simulated source. Future investigations would involve more sophisticated smellzones, perhaps with overlapping smells that could be wafted together to create a cocktail of the different smells that would have been part of a Bronze Age settlement.

This type of programmable, *in situ,* and embodied way of investigating smell within the landscape is a unique approach and is one with great potential. Of course, it should always be remembered that, while we can recreate or approximate the smells to provide a comparable biochemical stimulus, we experience them with 21st century noses, and therefore they may not get us closer to how smells were experienced. We may have the same corporeal reaction, but our cognitive or affective reaction will be nuanced with our different cultural overlay. To return to Merleau-Ponty, the indeterminate features of the smell which evokes memories within us (a barbecue may remind us of long summer afternoons on the beach) may have had a very different significance to the Bronze Age inhabitants (a reminder of the large feast on the summer solstice). Again, what is important in this case is the study of the *structure* of the experience: by providing the smell it is possible to simulate the experience of a certain smell being there, even if the smell itself may have a different *meaning* for any number of people.

How might this change our interpretation of the Bronze Age in south west Britain? As Bartosiewicz (2003) has shown, many settlements throughout antiquity have been organised in a way that minimises exposure to 'bad' smells. For instance, the livestock slaughter areas or hide-tanning areas are usually situated outside the settlement (Bartosiewicz 2003). However, “the crude archaeological record has seldom preserved comparable information on more delicate scents, especially those related to ancient human metacommunication” (Bartosiewicz 2003, p.190). The embodied GIS (with the Dead Man's Nose) should be used as a companion to the exploration of an archaeological landscape, simulating both the delicate and the more robust scents. *If* these roundhouses smelled a certain way, how would that affect the experience of living and working in the settlement? What questions would that raise? Would certain buildings be placed in certain positions to minimise the smell of the animal pens? Perhaps there was one central cooking hearth where all the inhabitants came together to cook their food; how would the smell of it affect the rest of the settlement? If there were some kind of industrial work going on, such as animal processing or tin working, what smells would these have created and can this tell us about where they might have been situated? These questions can now be explored bodily, by using the smell device I have created, but importantly, they are all tied to a *model* created within the GIS. This means the areas in which these smells occur can be changed at will, explored or changed as work or interpretation continues on the site. By mapping the smell zones of the Tavoliere Plain, Hamilton and Whitehouse were attempting to “provide groundwork for the exploration of the mundane plurality of experiences that constitute daily life” (2006, p.65); by using the embodied GIS it is possible to build on this and *simulate* each of these experiences, individually placing certain smells depending on a hypothesised use of a building, for instance, and thereby enabling us to tackle the plurality of experiences one at a time and perhaps isolate patterns that might not have previously been obvious.

Sound

A similar model can be created for exploring the sounds of a site. Archaeoacoustics have been studied in greater depth than olfactory archaeology, with the major work being a set of collected papers from a conference on the topic held at the McDonald Institute in Cambridge (Scarre & Lawson 2006). Most work on archaeoacoustics has explored the properties of enclosed spaces (see Blesser & Salter 2007) such as caves (Reznikoff 2008), theatres (Lisa *et al.* 2004) and churches (Fausti *et al.* 2003), and much is concerned with the acoustic aspects of prehistoric monuments, such as stone circles or chambered tombs (Mortimer & Pilkington 2011; Watson & Keating 1999), or the more well-known monuments such as Stonehenge (Fazenda & Drumm 2013) and Avebury (Watson 2001). For an excellent review of the increasingly extensive literature, see Mills (2010). With the exception of Mlekuz's work (2004) on the impact of church bells on the landscape, however, very little seems to have be undertaken at a landscape level.

Mlekuz explores in detail the concept of the *soundscape*, taking as his inspiration the definition by Murray Schafer and the World Soundscapes Project (Schafer 1977), who sits the soundscape in direct opposition to an acoustic space. “An acoustic space is the profile of a sound over a landscape, the area over which it may be heard before it drops below ambient level. This edge of audibility is called the acoustic horizon. The soundscape is a sonic environment, with emphasis on the way it is perceived and understood by the listener” (Mlekuz 2004, para.2.2.1). In this Mlekuz is separating the physical manifestation of a sound (the acoustic space) with the affective nature of the sound on a listener (the soundscape). Schafer identifies three different types of sound, the undifferentiated background sounds such as the sound of the sea to a sailor (*keynotes*), sounds that are made to draw attention, such as the crying of a child (*foreground sounds*) and finally, sounds that have a particular significance to a community, such as church bells ringing (*soundmarks)*. Mlekuz explores these categories further, drawing on the work of Gibson (1986) and Ingold (1993; 2011) explaining that the soundscape is not simply a sound map of the environment, but instead it is a sphere that surrounds a person in the landscape and moves as they move. Mlekuz develops a GIS-based model of the soundscape in an area of Slovenia, specifically of the soundmarks of the churches in the region. He uses a similar methodology as when creating fuzzy viewsheds (see Chapter Five), by using the data in the Digital Elevation Model to create 'sound shadows' which are then combined with the acoustic horizons of a particular sound from a particular location to create a fuzzy map of where that sound could be heard from. The final result is a map that provides the fuzzy audibility levels of various sound sources in the landscape that can be queried from an individual location.

Although Mlekuz succeeds in creating a fuzzy acoustic soundscape from the perspective of a person in the landscape, it is not clear how this can then be moved dynamically. In order to use a similar approach within the embodied GIS, the fuzzy acoustic map would need to be calculated on-the-fly as the user moves through the landscape. Mlekuz's algorithms are computationally intensive: as an example, a single Mlekuz soundscape that I calculated for House 35 on Leskernick Hill took over twenty-five hours to create on a 2.2 GHz Intel core i7 laptop with 8GB of RAM. This means they would not be feasible to run on-the-fly, especially not when using the relatively small processing power of an iPad. Therefore it is necessary to simplify the soundscape for use within the embodied GIS as it currently stands. It is possible to use the in-built functionality of Unity3D to simulate a soundscape. The Unity3D gaming engine has its own 3D audio modelling algorithm, which unfortunately is not as sophisticated as Mlekuz's and does not by default take account of the topography of the game world. It does, however, allow for the placement of 3D 'AudioSources', which can have a buffered drop-off in volume depending on how far away they are from the user. This means that within the embodied GIS, sound sources can be placed and buffered in the same way as the smellzones above, and they will become louder or quieter depending on the distance from the user. To simulate the occlusion of the objects in the landscape (and the landscape itself) I authored a script that used the mass of the 3D models (such as the houses) to occlude the sounds (Appendix One, *OccludableAudio.cs*). This has the result that the sounds from within houses are louder when you are inside the house itself, but are blocked by the walls when outside. It also means the sound comes through more clearly when walking past the open doorways.

To demonstrate this, I set up a series of audio sources within the virtual roundhouses of Leskernick Hill, and attached a simple general background sound of people talking and working. These represented the keynote sounds of the settlement. The fall-off distances (buffers) of these sounds were calibrated using the data collected during the phenomenological fieldwork on Leskernick (see Chapter Six), with the occlusion being handled by the custom script described above. By using a set of noise-reducing headphones plugged into the iPad, the user must listen to the sounds that are being fed to them through the AR application to the exclusion of the modern ambient sounds, akin to wearing a virtual reality headset. An alternative would be to use bone-conducting headphones, a device that sits on the bone in front of the ears and directly vibrates the inner ear bones, creating the sounds and leaving the auditory canals unobstructed so the user can hear everything going on around them in the real world. This approach is a type of 'Hear-Through AR' (Lindeman & Noma 2007, p.177), and effectively melds the real world sounds with the virtual sounds. When working in a landscape such as Leskernick Hill, the keynote sounds of birdsong and wind noise are ever-present and therefore, rather than simulate them, the existing modern soundscape can instead be augmented with the virtual.

Figure 94 - The AfterShokz (http://www.aftershokz.com/) bone-conducting headphones allow ambient sound to be heard, while virtual sounds are conducted to the inner ear via vibration of the zygomatic bones.

By linking the sounds to the GIS data, we effectively create a simple version of Mlekuz's soundscape, the sphere or bubble that exists around the user – as the sounds change depending on the user's location. As Mlekuz argues, “sound does not pre-exist. It exists only when being performed. Therefore, what we hear is always an activity. Sound is subject to rapid fading: spreading outwards from its point of emission, and dissipating as it goes, it is presented only momentarily to our senses (Ingold 1993, pp.161–162). As such, sound creates both time (when it is performed) and space (where it fades)” (Mlekuz 2004, para.2.2).

A field test of the methodology revealed some important observations. I used the location-based AR application as outlined in Chapter Six, with the addition of the audio sources centred on each of the houses. At first, the occlusion of the sounds by the mass of the houses was a little disconcerting, as obviously the buildings themselves do not exist. However, the sounds came to act as auditory markers as to where the doorways of the houses are. This then became a new and unexpected way of exploring the site. Rather than just looking at the remains of the houses and attempting to discern the doorway locations from looking at the *in situ* stones, I was able to walk around the houses and hear when the sounds got louder – which indicated the location of the doorway as recorded by the Stone Worlds team. The experience of the site changed, with interpretations about doorway locations being gently nudged via my ears instead of relying solely on vision. Initially then, an auditory BiP was experienced, as it was not clear why the sounds were getting louder or quieter. However, when coupled with the visual representation of the houses on the iPad screen, this BiP was reduced, and equally, the BiPs from the visual representation were also reduced as the two senses combine to create a greater feeling of presence.

The addition of the audio sources also allowed an exploration of the effects of the wider landscape. In the same way as with the visual AR aspects, I used the virtual landscape to occlude the virtual sounds. When used on site in the AR application, this virtual landscape is 'overlaid' onto the real landscape and therefore the effects of the virtual landscape on the sound appear to be reflected in the real landscape. This meant I was able to experiment in the real world and attempt to discern what effect the valleys would have had on sounds coming from the houses. This system can be used in conjunction with the visual AR aspects and provide more depth to the experience and allow different aspects to be explored. It is important to reiterate that these audio sources are set *within the GIS environment* – and therefore could be coded to represent certain areas of known activity, such as working areas, kilns, cooking areas, *etc.* Crucially these sounds are calibrated by using the results from the phenomenological fieldwork, again showing the embodied GIS as a bridge between the GIS data and the on-site experience. Therefore, in the same way as with the smellscapes, it is possible to use the AR soundscape to ask questions using the GIS data within the real environment. For instance, if people were working in this area, what sounds would be produced and how would that permeate across the settlement? If animals are kept in a certain place, would those noises be heard at all times? What relation do these sounds have to the ritual areas, *etc.*? The various scenarios can be entered into the embodied GIS and then explored *in situ*, by moving around the site and hearing how the soundscape changes. These type of questions become particularly relevant when thinking about the use of different houses, for instance, the 'Shaman's Houses' on Leskernick Hill were set apart from the other houses. By simulating different sounds from within the 'special' houses one could investigate their relationship with the rest of the settlement not only spatially, but also aurally. As Hamilton and Whitehouse suggest for the Tavoliere Plain, the socialising aspect of sounds and what they mean for the feeling of a settlement could be explored. By using the embodied GIS on the PSCA walks, the investigators would also be able to comment on the feeling of entering and leaving the settlement in terms of the cacophony of sounds gently fading away or becoming louder as they moved across the hills.

Comparing observations made during the phenomenological fieldwork with the AR soundscape application shows that the model as currently built within Unity3D does not accurately represent the sound dynamics of Leskernick Hill. For instance, there were examples where our fieldwork demonstrated that a bell should have been audible in the valley, but it was not audible when using the AR model. As was discussed at the start of this section, a truly accurate acoustic map of an open landscape is extremely hard to create without specialist equipment. Even when using the algorithm outlined by Mlekuz, the computational cost of just one soundscape is extremely high and these problems are compounded when using a dynamic listener who is moving through the landscape. The script that I have written in Unity3D is a somewhat blunt tool: if there is something between the listener and the sound (landscape, house, *etc.*) then the sound volume will be dramatically reduced. The script does not model the subtle diffraction of sound over and *around* topography, or take account of atmospheric pressure or the effects of the wind-speed (in some cases quite extreme, as shown in Chapter Six). As Mlekuz himself admits, “...sound propagation is an extremely complex process as it depends on a range of ill-defined variables and therefore it can never be precisely recreated" (Mlekuz 2004, para.5). In addition, as this methodology uses the location-based AR application described in Chapter Seven, it is prone to the same GPS positional errors, meaning that sometimes the user is misplaced within the augmented world and the sound sources appear to be emanating from the incorrect locations.

The AR soundscape model that I have outlined should therefore only be used as an exploratory tool. Detailed field-testing and evaluation is needed to refine the model, but even the most sophisticated model is unlikely to be an absolute predictor. Local conditions vary so much that it is unlikely that even the real results will be consistent from day to day and therefore there needs to be a certain amount of fuzziness built into the design (c.f. Mlekuz's fuzzy acoustic maps 2004). However, I have shown the soundscape can be another way to explore the GIS data already collected in reality on the ground. It can be a useful tool for thinking with and when coupled with the visual and olfactory elements of the embodied GIS it gets us closer to recognising the need to consider the entire sensorium when creating a GIS dataset. More than this, it allows us the exploratory and modelling power of a computer-based solution, with the bodily experience of being in the landscape. However, there are another two senses that I have not yet considered that should fit within the embodied GIS, though they are rather harder to incorporate into a useful mobile augmented reality application.

Taste

Taste in Augmented or Virtual Reality is one of the hardest senses to properly simulate (Lindeman & Noma 2007, p.177), and has been called the "last frontier of virtual reality" (Iwata *et al.* 2004). The main reason for this is that it is very closely tied to the other sense-systems, such as smell, sound and haptic sensation (biting and chewing), so multi-modal solutions are needed. This means that in order to properly simulate taste – or at least the sensation of eating something – it is necessary to either actually eat something or to insert a tube into the mouth and pump in liquid food. The most prominent example of using taste in AR is provided by the MetaCookie+ team (Narumi *et al.* 2011). The Japanese team investigated a multi-modal approach to simulating and changing the flavour of a plain biscuit. By using a head-worn display and a head-worn olfactory dispenser they gave each of their participants a plain biscuit and asked the participant to choose the flavour of biscuit they wanted to taste (*e.g.* chocolate, almond, strawberry). An AR marker was branded onto the plain biscuit and the appearance of the biscuit changed using marker-based AR via the head-worn display. The appropriate scent was then filtered through to the nose of the participant as they ate the plain biscuit. In 79.3% of their trials the participants detected a change in the taste of the biscuit and in 72.6% of those they identified the taste as being the one that they had selected.

Figure 95 - The MetaCookie+ system (Narumi et al. 2011, fig.10). *As can be seen, the interface is rather cumbersome.*

Where the MetaCookie+ participants chewed actual biscuits, a team from Tskuba University in Japan (Iwata *et al.* 2004) concentrated on creating a haptic device that simulates the sensation of biting into a rice cracker. The device sits within the mouth and provides physical feedback against the teeth as it is bitten, the force of which changes depending on the type of food being simulated (hard for a rice cracker, soft for cheese, *etc.*). In addition to the haptics of the biting sensor, the vibrations created by chewing were simulated by using a bone-conducting headset to vibrate the zygomatic bone, and taste was dispensed by using a tube to deposit a mixture of the five different types of taste (sweet, sour, bitter, salt and umami [savoury]) directly onto the tongue. In their experiment they did not use an olfactory dispenser or a HWD (such as the ones employed in the MetaCookie+ experiment). The results showed that 96% of the participants could recognise the virtual food that they were eating.

As these two examples show, it is clearly possible to simulate the sensations of tasting a food, and to use all of the senses to convince the body that it is eating a certain type of food. However, the multi-modal nature of these devices mean that they are more suited to a laboratory environment, rather than for use in the field. In addition, these devices have been produced for specific reasons, to aid in the treatment of people with over-eating or obesity problems (MetaCookie+) and to aid in the recovery of people who find it difficult to chew (Tskuba University). The exploration of taste and food within archaeological contexts is a worthwhile and important endeavour (see Hamilakis 1999; Bray 2003; Twiss 2007) and it can reveal new insights about both social structure and identity (Hamilakis 2000) but it would seem at this moment it may be easier to use actual re-created recipes and eat them *in situ*, than it would to use some kind of mediated device. Perhaps the augmentation of taste is as simple as taking a packed lunch of grain pancakes and meat stew (made using as 'authentic' a recipe as possible) onto Leskernick Hill and eating it whilst sitting outside one of the roundhouses, enjoying the sounds and view through the rest of the embodied GIS interface.

Touch

The final sense that it may be possible to explore using the embodied GIS is touch. Touch, or haptic feedback, is of critical importance whenever humans interact with objects. When either picking objects up or interacting and manipulating them in some way, humans instinctively rely on the inherent haptic cues and feedback received from these interactions to inform about the properties of the object, such as texture, shape, weight, hardness, stiffness *etc.* (Osafo-Yeboah *et al.* 2013). Haptics are a bi-directional system in that we can simultaneously touch something as well as exert force upon it.

Haptic interfaces are used quite frequently within virtual reality models and include devices such as virtual reality gloves (Thomas & Piekarski 2002), surfaces that change with piezo-electric currents (Winter & Perriard 2011) and static force-sensitive arms (Silva *et al.* 2009). The key to the success of a haptic device is to generate accurate feedback when interacting with a virtual object. When I see the augmented model of the roundhouse, I also want to be able to reach out and touch the walls of it. This is difficult to achieve even when in a laboratory, but the problems are compounded when attempting to use it in an outdoor AR system as there are "...a varying number of coordinate systems (physical world, augmented world, body relative and screen relative) within which the user must work" (Thomas & Piekarski 2002, p.168). Where the visual AR interface needs to understand the registration of the virtual objects onto the video feed, the haptic interface also needs to understand where the fingers are in relation to the virtual objects. As I have demonstrated, GPS and computer vision registration methods are not entirely accurate and when coupled with the need to understand the exact locations of the fingertips a useable outdoor haptic device becomes extremely difficult to create. There are possibilities for using a computer-vision based solution for detecting the location of the fingertips in a 3D space (Oka *et al.* 2002; Chang *et al.* 2013), however, the fingers would only be tracked when in view of the camera.

The nature of the interaction is also key: by providing small vibrations the user has some notion of being in contact with a virtual object – but if it is a wall of a roundhouse, then I should not be able to push my hand through it and so need some kind of force-feedback to limit my movement. Force feedback can be achieved in haptic devices (such as the Phantom Omni haptic device [Silva *et al.* 2009]), but for mechanical reasons these are usually limited to the laboratory as the physical mechanism to produce the force-feedback can be quite bulky or complex.

To fully address the BiP from a lack of haptic interaction, the registration of the hand, fingertip and rest of the body would have to be extremely accurate, in addition, the interaction itself would have to feel 'realistic'. If this is not the case, then further BiPs will be introduced and especially if the registration does not match the visual representation of the virtual objects (i.e. I can feel it, but it looks like I am not touching it) then the Breaks in Presence could potentially be worse than without a haptic interface. At this time, then, haptic interfaces are not suitably developed to be easily fitted within the embodied GIS, however as with the other multi-sensory BiPs technological innovation is moving forwards at an incredible rate and it would seem unlikely that a suitable haptic interface is impossible.

In addition to this, a question remains as to the purpose of recreating a haptic environment and how this may be helpful for investigating the Bronze Age. From a landscape perspective, the simulation of haptics (at least through the fingertips) may in fact not be particularly instructive. However, when coupled with the other embodied GIS elements (such as sight and sound) the absence of touch would leave a noticeable gap in our feeling of presence. As alluded to above, if I can see a roundhouse, hear the inhabitants and smell the food cooking within, but I cannot touch the walls, then my feeling of presence is broken. However, due to the very personal scale of touch (literally at arm's length) the archaeological questions that could be answered on a landscape-scale are quite limited.

Social BiPs

Perhaps the biggest problem for archaeologists adopting any kind of approach that starts from the embodied experience of the individual is the social aspect. As I alluded to in Chapter One, the sociological element of an experience is extremely important. I have shown, it is possible to recreate many aspects from the archaeological record – the type and location of roundhouses, the possible location and alignment of stone circles, even to recreate possible prehistoric meals *etc.* However, what we cannot do (except through efforts of the imagination more associated with the literary than the scientific world) is to move through the landscape in the body of a social individual from a past society, for instance a tin worker or a child from the Bronze Age settlement. It may be that this objection is insuperable and means that the social cannot really be included in analyses of this kind – at least not in terms of the nature of a particular past society. However, it *is* possible to use a mixed reality approach to experience the AR content alongside other people and have a modern social engagement with the experience. This is akin to undertaking the phenomenological fieldwork as a two-person team – allowing the experience to be shared and discussed and viewed from more than one perspective at a time.

It is relatively easy to implement a multi-user environment for the embodied GIS. Unity3D offers the facility for networking multi-player games, and this can be used to connect a number of different devices together. In order to implement this a network server and hub is required to coordinate the information being sent and shared between the devices. When used in a landscape setting the necessity for this extra hardware may be problematic, as the server and hub will need to be continually powered up and the users may be limited by the range of the Wi-Fi network.

However, if the technical hurdles can be overcome, each of the participants would then be able to interact with all of the augmented content in the same way. Effectively we would be using the embodied GIS to anchor many of the elements of the experiment. Instead of requiring different archaeologists to interpret elements of the past in their own way (akin to Bender *et al*.'s use of humans to represent houses) we have the opportunity for the parameters of the experiment - the building blocks of the experience - to be fixed for everyone, ensuring all participants are reacting to the same augmented elements. This does not in any way affect their own subjective experience of these, but it goes some way to creating a hypothetical environment that can be tested in the same way with a number of users, and also to experiment with situations in which there is more than one user present. Once again, the embodied GIS is providing a way to pull apart the experience and create and isolate certain parts of it which can then be recreated for one or more users. It may not allow us to experience the landscape exactly as a Bronze Age tin-worker, but it does allow us to test hypotheses about the structure of the settlement and suggest reasons for the placement of specific elements.

Solving all the BiPs?

As I have shown in this chapter, the BiPs that have been raised during my field trials of the embodied GIS applications can be addressed; however, due to the limitations of both the hardware technology and the software algorithms, some of the solutions are currently not possible. It is also clear that the proposed solutions to some of the BiPs will raise further BiPs. It is unrealistic (and possibly undesirable) that it will be possible in the future to resolve every single BiP, as this would be a complete recreation of past worlds. As archaeologists we are trained to look at and interpret evidence of the past from an objective perspective. By using the embodied GIS we can explore this evidence from a body-centred perspective, but we will always be looking with an archaeologist's eye to discover more about the past. Much as the danger of over-rapport (Miller 1952) or 'going native' (O'Reilly 2009, pp.88–89) has been a problem within modern ethnographies, a BiP-free embodied GIS would reduce the archaeologist to being a fully-integrated participant/observer of the society, without space to think or reflect on the experience. This is the key to the embodied GIS: it is not designed to be a completely immersive experience in which to get lost unthinkingly, instead, it is a tool and a method *to think with*. Just as GIS is a tool for modelling, analysis and experimentation, and phenomenological fieldwork is a practical method for exploring the landscape from a body-centred perspective, the embodied GIS is a tool to work with and provide new ways to examine the results from both of these techniques. If we eliminate all BiPs then the experience does not become one that is abstract and to be examined, it simply becomes a new life. Therefore, it is vital to make the best choices, based on the questions asked. If we are interested in the way the houses of the settlement occlude views of Roughtor, then the size and shape of the houses is vitally important, but the colour of the walls or the smell of the fire is not.

In this chapter I have shown examples where the embodied GIS may be applicable to a study of Leskernick Hill. For instance, by using the smell interface it is possible to test hypotheses about the placement of certain buildings within the settlement. If certain areas were used for animal pens or processing how would the smell permeate the settlement, how would that affect the experience of the site, and would it affect the choice of placement of other buildings? By using occludable sounds, we can ask questions about the different sounds that may have been used throughout the settlement. If rituals were undertaken using bells or singing, where on the settlement would this have been audible? If I were in a particular house would I have been able to hear it? How would the placement of the doorways, or permeability of the house walls have affected this? The taste and touch interfaces are much less developed than the sound and smell interfaces, and the scale of the senses is on a much more intimate scale. These senses do not perhaps bring anything concrete to the study of the Leskernick Hill landscape; however, by bringing these senses into the mix, we can deepen the feeling the presence and this immersion may provide insights that were not possible before.

As is clear from this chapter, the interfaces for the senses other than vision (with the possible exception of sound) are currently under development and are not as sophisticated as the visual interface outlined in the previous chapter. As this is the case, they are also currently not as accessible to non-specialist archaeologists. The Dead Man's Nose system itself represents a fair effort in terms of programming (four weeks of programming and testing) and money (the Arduino board and associated equipment cost in excess of £150). However, as the system and technologies are developed they will become increasingly more accessible, and, as with the iPad interface described in the previous chapter, provided user interaction with the system is given priority in the design then the embodied GIS should be able to be used by a non-specialist archaeologist. Regardless of the interface, however, the embodied GIS is the combination of a 'normal' GIS and a phenomenological investigation. If a project already has a GIS set up then it would be relatively easy to import the data into the format needed to use the embodied GIS system and to then use this system to explore questions from a body-centred perspective.

The overriding strength of the mixed reality approach is that we are operating in only one part of the MR continuum. This means that it is possible to find a way into the site in question at any point in the continuum, from the entirely virtual to the entirely real reality. The power of using all parts of the continuum offers new ways to explore landscapes that combine completely computer-generated content that would be impossible to create in the real world due to expense or time constraints, to augmenting the landscape with real objects, such as full-scale, real-life reconstructions of roundhouses. By creating objects and content along the length of the continuum, the potential for experimentation becomes immense, and as long as these experiments are properly documented and the BiPs identified, then the same experiments and recreations can be rerun at different times by different people who may solve some BiPs or experience different ones. These differences are the key to understanding the reaction of the human being to the situation being recreated and our subjective experience of the questions and answers we are trying to solve.

Chapter 9 - Conclusion

When I initially embarked on the research for this thesis, I had hoped to address the space in the 'middle ground' between a experiential and a computational approach to the landscape. I wanted to find ways to bring together the two seemingly polemical techniques of landscape investigation, landscape phenomenology and Geographic Information Systems. Whether this middle ground even exists is currently under debate (as evidenced by the recent special issue of the *Journal of Archaeological Method and Theory* 2012 vol. 19:4), but the divide is certainly evident. Mark Gillings suggests that rather than trying to link the two approaches together we should instead be actively working towards developing new conceptual frameworks that are sensitive to the currents and debates in critical thought, but also bring together the potential and possibility of emerging spatial technology (Gillings 2012, p.610). This is what I have strived to achieve throughout this thesis, and I believe that a mixed reality approach using the embodied GIS in the ways I advocate is not only a new *conceptual* framework, but also a *practical* tool that can be employed when investigating archaeological sites.

My study of philosophy of mind and the tenets of phenomenology in Chapter One provided a structure in which to consider the more nuanced discussion of the embodied experience. By examining the philosophical frameworks that the theory of perception and experience are built on, I showed that there is a divide between how we experience the world internally and how this experience manifests itself externally. Phenomenology has often been excluded from the philosophy of mind, because it is introspective and implies that 'feelings' cannot be externally ratifiable. As we will recall, in order for modern materialist philosophers to argue that everything in the mind comes from material substance, they need to be able to observe the physical causes (for example, specific brain neurons firing) of subjective feelings. Husserlian phenomenology, however, seeks to examine the *essences* and *relationships* of the experiences, not the 'raw feel'. It sidesteps the need to explain how these feelings are created and instead calls for a examination of their interrelationships. These interrelationships are also of a temporal nature, “...every subjective process has its internal temporality” (Husserl in Ferguson 2001, p.240). We can look at our own experiences, but these are as temporally contained as the experiences of the people in the past. Although by listing and isolating different aspects of the experience we may not be able to 're-feel' the experience of past people, we may instead be able to get closer to understanding how those experiences were constructed and what elements of their experiences we can and should investigate. As with Searle's Chinese Room experiment, even if we don't know exactly what the semantics of the experience were (and never can), we can look at the syntax and context of that experience and draw conclusions about what that may have meant for people living in the past.

This requirement to list and document the relationships and essences lends itself well to the Arc of Intentionality and a study of Breaks in Presence. The Arc of Intentionality, first introduced by Merleau-Ponty as the 'intentional arc' and subsequently built on by Turner, brings together the concept of intentionality (all feelings are *about* something), and Gibson's use of affordances. Turner's use of the AoI was as a heuristic approach to question aspects of presence, and this is one of the ways in which I have used it; however, the AoI is also an excellent tool for documenting the *nature* of experience. It brings together the cognitive, perceptual and corporeal states, with the 'external' nature of the affordances, the “places, spaces, people and events” (Turner 2007, p.132). As outlined in Chapter Two, affordances can never be thought of as solely 'external'; they are an interplay between the environment and the observer, as Gibson wrote in 1986:

> “An affordance cuts across the dichotomy of subjective-objective and helps us to understand its inadequacy. It is equally a fact of the environment and a fact of behaviour. It is both physical and psychical, yet neither. An affordance points both ways, to the environment and to the observer” (Gibson 1986, p.129).

Using the AoI combines intentional states and affordances, which fits well with my discussion of the indeterminate features of space - features that are not directly perceived, but which are known to exist – for instance, the invisible end-point of the road that snakes off into the distance. The AoI's breakdown of affordances and intentional states into the separate categories of affective, social, corporeal and cognitive/perceptual provides a useful framework for discussing the essences of experience and relationships between experiential states and I have used this framework throughout the thesis for documenting both the phenomenological and computational aspects of my research. This proved successful, as I was able to dissect each experience (in the Husserlian sense), but also to comment on which aspects of the environment (both real, i.e. rocks or slopes, and virtual, i.e. roundhouse reconstructions) had an influence on the users of the embodied GIS.

Following my discussion of the philosophy of perception and some previous ways that GIS has been used to recreate and investigate past perception, I explained the various levels of Mixed Reality (along the Schnabel scale) and the different delivery mechanisms and software/hardware platforms that can be used to create an MR experience. In this thesis I concentrated mainly on the Augmented Reality aspect of the Schnabel scale, however, as I have also shown, the embodied GIS lends itself well to other dimensions along the scale. For instance, Diminished Reality can be used to remove aspects of the modern landscape that may not be desirable, in the same way as one can omit modern buildings when undertaking GIS-based analysis of a LiDAR dataset. As the technology advances, this diminished reality can be enacted almost in real-time (see Herling & Broll 2010; Leao *et al.* 2011), allowing the user to choose to virtually remove unwanted elements of the landscape at will. In the future, it may even be possible to use Augmented Virtuality (in which the real landscape is recorded using 3D cameras and microphones, but which can be augmented in real time) for recording the process of archaeological excavations and highlighting aspects of them digitally as the excavation proceeds. Full Virtual Reality has been used for a number of years for archaeological applications (see Chapter Three), and as the continued success of the International Symposium on Virtual Reality, Archaeology and Cultural Heritage (VAST 2013) shows it is going from strength to strength.

Although the other dimensions on the Schnabel scale have archaeological application, I chose to concentrate on Augmented Reality. I made this decision as I believe AR has the greatest potential for combining Real Reality and Virtual Reality in a way that is most useful for archaeologists, and it allows us to takes the greatest advantage of both the experiential approach and the computational approach to landscape study. By presenting my concept of the embodied GIS in Chapter Three, I argued that rather than attempting to completely create a whole new reality within a computer, disconnected from the landscape in question (the VR approach), or to completely disregard the advantages of computational analysis of the landscape while studying the real landscape (the landscape phenomenology approach), AR technology can be used as the glue between these two worlds. The embodied GIS is my vision for how this could happen and in Chapters Seven and Eight I demonstrated how this could be realised practically.

Does the Embodied GIS Work?

When I introduced my concept of the embodied GIS in Chapter Three, I outlined a number of criteria that I believed were necessary for an embodied GIS to be effective. I will now discuss each of these.

1. Combine desktop GIS data with an interface that allows the data to be experienced directly within the landscape in question, using immersive or semi-immersive technology.

As I have demonstrated, the Augmented Reality technology I have implemented can be used as an interface to experience desktop GIS data within the landscape in question. I chose to use an Apple iPad as the delivery mechanism for a number of reasons, including ease of development, low cost of the equipment and the portability of the device. The iPad is a semi-immersive device, as it requires the user to be holding it in front of their face as a 'Magic Mirror', rather than the content being directly augmented into their view (as could be the case with a Head Worn Display). In Chapter Seven, I identified the BiPs that using such a device creates, and in Chapter Eight suggested ways in which these BiPs might be addressed. It is worth noting that even though BiPs are produced, it does not necessarily denigrate from the experience. If the aim were to have a fully immersive experience, then a reduction of BiPs would be essential, however, if the embodied GIS is being used as an interface to examine GIS data, then the realistic nature of this is not paramount, as instead one might be investigating the accuracy of the GIS model or the way in which the actual landform might have occluded the modelled elements. As I showed in Chapter Eight, the ongoing development of new technology will likely go some way towards reducing the BiPs caused by a less-than-fully-immersive experience. I would stress, then, that full-scale realistic reconstruction is not always the aim, and in the same way as Bender *et al.* (2007) experimented by wrapping stones in coloured film, the addition of the virtual data may be simply to give an *impression* of how things may have been, to stimulate further debate and discussion. The process of recording the BiPs, however, is important as these act as the documentation of the experience itself, recording the conditions of the experiment.

2. Encourage the inclusion of the other senses beyond just sight; for example, sound, smell and touch. Make use of emerging technologies to augment these other senses.

In Chapter Eight I explored ways in which the other senses could be added to the embodied GIS. It is clear that at present, the technology for augmenting non-visual sensory inputs, at least for outdoor applications, is not as well developed as the visual technology. Despite this I showed how existing technology can be used to augment some other senses (olfactory and auditory) into the embodied GIS. This is an area that needs to be developed further; however, even my comparatively limited experiments demonstrated the strength of such an approach. This was particularly apparent during my experimentation with soundscapes, during which I discovered a different way of exploring Leskernick Hill, by navigating using sound alone. This not only enabled me to explore the soundscape dynamically and in real time (something that has not yet been demonstrated using a GIS approach), but also augmented and tested the findings from my phenomenological sound experiments. I was also able to suggest ways that site-specific questions might be approached, such as how the use of bells or wooden instruments during rituals may have impacted the placement of houses in the landscape. The necessity for discussion and inclusion of the other senses demanded that I consider how they might be enacted with the embodied GIS, and this in turn demanded that I consider them in terms of a full exploration of the archaeological landscape. It is very easy when creating a landscape GIS to concentrate on the visual, as this has been the traditional way of approaching perception in the landscape (see Chapter Three), and it is equally easy to concentrate on what can be seen during phenomenological investigation (as evidenced by a majority of the phenomenological documentation recording views from various parts of landscapes, see Brück 2005; Fleming 2006). However, the embodied GIS demands that the user thinks about the other senses as they are being actively augmented into the experience. BiPs occur almost immediately if the other senses are not addressed. It feels strange to see a roundhouse, but not be able to touch it, hear the activity inside, or smell the thatch: the Arc of Intentionality is broken. The very act of creating a visual experience brings into sharp focus the elements (the affordances) of what is missing. This then asks us as archaeologists to consider these missing elements and try to find ways to represent or simulate them. The embodied GIS in this case can be used as a heuristic to remind us to consider the other aspects of experience, and not only those that are the simplest to model or the most widely studied. This encourages other questions to be posed, such as what difference it makes to the settlement layout if the *smelly* animal processing areas were in the centre, or how far away does one have to be to *hear* the ritual drums being beaten in the stone circle?

3. Create a feedback loop, so that the embodied interface does not just become a window on to the data, but allows instead a two-way data exchange.

As I have stressed throughout this thesis, the embodied GIS is not simply a tool for viewing data, it is also a way to explore and change the way we think about the archaeological landscapes in question. It can be used to inform our current models and demonstrate where they may be lacking in precision or where they simply do not properly represent a reality in the way we intended. My proposed methodology for creating the embodied GIS ensured that the data pulled into the application were drawing directly from the GIS data themselves. Therefore, if the data in the desktop GIS are changed, the view of those data in the embodied GIS is also changed. This connection should ideally be two-way, with the embodied GIS interface allowing changes to be sent back to the desktop GIS. Unity3D records the three-dimensional position and attitude of all of the objects within the AR scene, and therefore the details of those positions can be included in the geometry of the two-dimensional GIS data. However, I did not manage to enact this as part of the applications that I field-tested, mainly because of the technical difficulty of creating a suitable user-interface for updating the GIS data. Real-time two-way data exchange is possible when the application is running on a desktop computer or laptop, as the mobile device (in my case the iPad) can be permanently connected via a wire. However, when in a landscape setting, this connection needs to be maintained and this is only possible using a Wi-Fi connection (or by carrying the laptop in a bag connected to the device via a wire) and of course requires power for the laptop.

4. Be multi-user and multi-device. The data should be able to be explored collaboratively and all users should be able to interact both with each other and with the data. The system should be able to run on multiple types of device.

One of the advantages of developing the embodied GIS within Unity3D is that it enables multi-user applications with a very limited amount of extra coding. Unity3D also supports a wide range of platforms, including Linux, Windows, MacOS and iOS (for iPhones and iPads) and Android (for other tablets and devices). The same application can be built and then deployed on any of these other platforms, allowing for true cross-platform functionality. This platform-agnostic approach is vital for the embodied GIS, especially as new devices suitable for AR applications are being released all the time, allowing the user a choice of their device, including the possibility of HWDs if required. However, my prototype application did not incorporate the ability to be deployed within a multi-user environment. There were a number of reasons for this. First, a multi-user environment requires a server to act as the data-broker between the users, to ensure that their sessions are all in sync. As explained previously, although a mobile server is possible in a landscape setting it brings with it problems of access, connectivity and power. Second, before developing for a multi-user experience, I wanted to properly test and evaluate the single-user embodied GIS. As I have demonstrated the effectiveness of this approach, the next stage of this research will involve widening the approach to a multi-user environment.

So although my prototype applications did not fulfil all the criteria that I initially set out for an effective embodied GIS, I hope I have shown that the missing elements can be dealt with quite easily within the current development framework, or will be in the near future with the advent of developing technologies and emerging AR devices.

How much does it cost?

When I have presented my ideas about the embodied GIS at conferences, one of the main questions I have been asked regards the cost of the system. In its simplest form, the practical embodied GIS consists of a pre-programmed smartphone application that communicates with a series of GIS files. As can be seen in Appendix One, I have authored a number of scripts that are required to run the application. The design, creation, authoring and testing of the system itself is a culmination of three years work; however, now that the system is in the prototype phase it can be used on any site that currently uses a GIS. The system is built on either Free or Open Source software (see Appendix Three) and I have made my code freely available via my weblog (Eve 2013). The hardware I have used consists of an iPad3 which currently retails for around £300. iPads and other tablet computers are becoming more ubiquitous on archaeological projects and their use for other purposes, such as on-site recording or documentation, means they are more likely to be available on archaeological projects in the future (Fee *et al.* 2013). As I discussed in Chapter Eight, the inclusion of the other senses in the embodied GIS means further outlay on some hardware (for instance the Arduino board used by the Dead Man's Nose costs around £145 and the afterShockz headphones around £35). These costs are not outside the purview of a modern archaeological project and as the system develops they are likely to lower.

The initial configuration of the system itself does require a level of computing knowledge that is beyond a non-specialist digital archaeologist, although I have provided a series of how-tos on my weblog to aid any archaeologists that would like to create the system. As the data are held within a GIS and I have already written the import/export/interface scripts, the skills required to configure the system are therefore not likely to be beyond an archaeologist trained in GIS techniques. Judging by my experiences, then, provided a basic GIS database and a Digital Elevation Model of the landscape in question are available, configuration and deployment of the system prior to being able to start the fieldwork should not take longer than three days.

The Production of New Archaeological Knowledge?

Throughout this thesis I have successfully demonstrated the potential of the embodied GIS to act as the bridge between phenomenology and computational archaeology and so to act as a new way to explore an archaeological landscape. The question remains, however, as to whether this is useful for producing new archaeological knowledge. What can such an approach add to our study of the past? During Part Two I explored the case study of Leskernick Hill in Cornwall, specifically examining the placement of the houses within the Bronze Age settlement. In addition, I examined the wider landscape and asked questions of the ritual, domestic and industrial activities that may have been taken place in the area. By undertaking a GIS analysis, followed by a phenomenological analysis of the Hill, I was able to discover new insights into the possible reasons for this settlement that had previously not been investigated in any great detail.

I began my GIS analysis at the micro-scale, attempting to discover more about the placement of individual houses on Leskernick Hill. The houses of the Leskernick Hill settlement have traditionally been thought to have been placed specifically to maximise the views of Roughtor, Brown Willy and the ritual monuments (the stone row, circles and cairns) (Bender *et al.* 1997; Bender *et al.* 2007; Tilley 1996). By using a new and innovative technique for visualising and processing the results of viewshed analysis, I created a series of spatial confidence maps. These maps showed that, contrary to the original suggestion by the Stone Worlds team that the placement of the houses was unusual, no matter where on the southern side of the Hill the houses were placed they would have been able to see these landscape and cultural features. The spatial confidence maps also revealed areas of the landscape that would not have been visible unless the houses were placed in specific locations. In particular, the analysis indicated that the Fowey river valley was an area of unusual visibility, suggesting that the inhabitants of the western settlement on the Hill may have placed their houses within the general settlement area specifically to command a view of the valley floor, something that had previously gone unregarded. As noted in Chapter Five, this may have been for a number of reasons, including the observation of domestic activities (water-collection, grazing, etc.), ritual activities (watery-places being of importance to some Bronze Age people) or industrial activities (the valley may have been exploited for eluvial tin). When I undertook the same analysis for the area of the southern settlement, it suggested that the houses had been placed to take advantage of a view of one of the stone circles, corroborating previous interpretations that the southern houses were erected to respect the ritual monuments.

Building on this analysis I investigated the possibility that the houses (micro-scale) and the settlements themselves (macro-scale) were placed for preferential views of the tin-streaming areas. Using a combination of further statistical testing techniques I was able to establish that, when compared to a set of random samples, the houses do indeed seem to have been placed to command views of the possible tin-extraction areas. Whilst my analysis was constrained to the micro-placement of the houses on the Hill and did not take account of the possible views from the other hills in the area, it clearly suggests that, even if Leskernick Hill was initially settled for other reasons, the houses themselves could well have been placed to provide good visibility of the tin-extraction areas. This conclusion was reinforced at the macro-scale by my creation of visibility fields (*c.f.* Gillings' affordance viewsheds [2009]) the analysis of which demonstrated that the houses were placed in the 'hot-spot' of the Hill that provided the largest view of the area of tin-extraction. When the two areas of settlement were looked at separately, the houses of the southern settlement seem to have been placed to afford unusually good views of the ritual area, that they would not have commanded had they been placed randomly within the southern settlement area.

As discussed in Chapter Four, due to a lack of direct evidence Bender *et al.* have remarkably little to say on the subject of the settlement at Leskernick and its relation to the tin resources. This lack of direct archaeological evidence means that we need to explore other avenues to approach this possibility. My GIS analysis indicated that tin extraction may well have been a reason for the settlement of the western side of the Hill and the specific placement of the houses. This conclusion is supported by the phenomenological fieldwork. The Phenomenological Site Catchment Analysis showed, amongst other conclusions, that Leskernick Hill sits within a bowl of hills that is obvious not just from the topography, but also from the effect it has on the body as one enters or exits. It feels as though one is entering a different world and the visceral effect of this was noted by all of the surveyors. However, to exit this bowl takes only approximately thirty or forty minutes of walking in any direction, and an hour's walk brings you into contact with over 150 other house circles. This connectedness to the 'outside world' in terms of walking time is coupled with a sense of visual enclosure. The Leskernick settlement was certainly a separate settlement, but it existed within a larger community of surrounding settlements. The PSCA also noted the possibility that the areas on the outside of the 'bowl' seemed to be situated in landscape more suitable for agricultural purposes. Clearly this is in need of further investigation, but when coupled with the possibility that the Leskernick settlement was based around tin-extraction, we might speculate that the surrounding settlements may have been providing agricultural support for the more industrial activities within the bowl of hills.

I have also suggested that the solution basins on the tors surrounding Leskernick Hill may have been used for the processing of tin. I was able to show by phenomenological experimentation that it would not have been onerous to carry water, tin or even wood to the tops of the tors, and that once there the basins would have been quite suitable for processing the tinstone. This interpretation does not oppose Tilley's assertion that the basins were used for ritual libations, it is in fact in tandem with it, especially if tin processing was considered a ritual activity (e.g. Bradley 2005). My sound and communication experiments showed a number of intriguing effects of the landscape surrounding Leskernick and suggested that sound may travel in unexpected ways, due to the reflection of the valley sides – allowing for the possibility of auditory communication over quite substantial distances. In addition, it was clear that communication with people working in the valley bottoms would have been easily possible from houses within the settlement. The results of this basic data collection were also used to inform the parameters for the GIS model of soundscapes.

The phenomenological fieldwork not only provided data for the embodied GIS in terms of baselines for the sound and visual communication distances but also provided an opportunity for me to think my way through the landscape. My discussions with fellow surveyors and the collation of their results allowed for a reflexivity that is not always evident when examining a landscape from a distance. Investigating the possible nature of the settlement as being based around tin extraction would not have happened had I not had to repeatedly physically cross the post-mediaeval tin-workings when undertaking the fieldwork. My interpretation of the 'Roughtor Effect' (the coming-into-view of Roughtor at a certain point along the stone row) being related to the tin-ground, in opposition to Tilley's suggestion that it related to ritually crossing a watery area, is a good example of how different interpretations of the same feature can produce very different results in the subsequent analysis of a site. Bringing Sue Hamilton's work (on the Tavoliere Plain) back to Leskernick Hill neatly closed a reflexive circle, and meant that my work was informed by nearly two decades of the development of phenomenological theory and practice. The phenomenological fieldwork asked a number of questions that required further investigation, and my GIS analysis supplied further evidence to support the hypothesis suggested by this phenomenological work. By undertaking the phenomenology and the GIS analysis in tandem, each informed the other and combined to produce new suggestions for the reasons for the house placement.

Bringing it all together

As I have established, using phenomenology and GIS in tandem has the potential to produce a new interpretation of the Leskernick Hill settlement. However, I took this approach further and combined the two approaches into one unified embodied GIS. As I conclude in Chapter Seven, the embodied GIS brings advantages to both. For instance, when analysing the landscape using GIS alone, it is easy to forget that the elements under study (the houses, the cairns, the standing stones) have a defined three-dimensional shape. Although this can be modelled within GIS, the granularity of the pitch of a roof or the rounded top of a standing stone are extremely hard to analyse. The AR interface allows this granularity to experienced directly in the field. The GIS analysis therefore works on a different scale, usually limited, at least in terms of viewshed analysis, by the resolution of the Digital Elevation Model. The AR interface allows the raw GIS data to be displayed at a much finer scale, using the real landscape as the Digital Elevation Model. As I showed in Chapter Seven it is then also possible to ground-truth the GIS data by overlaying it on the real landscape to reveal where the errors lie, and also to implicitly reveal to the GIS practitioner how far away from real reality their model of the landscape is. This is not a criticism of the GIS approach; on the contrary, sometimes GIS models are extremely accurate representations of the landscape. Instead, the AR approach can be used to calibrate, error-check and ultimately improve the GIS dataset.

From a phenomenological perspective the AR interface brings a number of advantages. It allows a model of the archaeological and historical landscape to be explored in a way that is not possible using simple props such as flags or wooden doorways. At the same time, it does not take away from the vital importance of being present on the site and experiencing the landscape through the body. The AR interface can be used if required, but it is not essential to use it continually. Instead, it provides an insight into the 'other' world that can be compared to the present day. It also provides a way to explore a reconstruction of the site without having to physically build the models, therefore enabling an exploration of complex views from viewpoints that would not be possible without some form of mediation. More importantly than that, it allows the experiment to be *reproducible*. By using the same GIS data and 3D content, different people can look through the virtual doorways or walk through the site using the AR application and have their view occluded in the same way every time – in contrast to the personal interpretation of the shape of the houses created by the original surveyors on the Stone Worlds team. It also allows for experimentation with the size and shape of houses, meaning that the models can be changed as the project proceeds in response to the excavation data or overall changing interpretation. Each house model can be individually tailored to reflect its individual life story, and this could of course be tailored temporally as well – allowing the exploration of the settlement at the beginning of its construction, during its heyday and finally as the settlement went out of use.

The embodied GIS, then, is not necessarily a stand-alone approach. Instead it can act as the bridge between the GIS analysis and the phenomenological analysis of a site. It brings both methodologies to the fore and allows them to be blended, providing a richness to both strands of investigation, communicating and ground-truthing the GIS data in a way that has not previously been possible, and at the same time, by only augmenting a limited amount of information, it allows a landscape-centred approach to be undertaken which keeps real reality at its core.

Final Thoughts

Previous use of Mixed Reality in archaeology has concentrated on its power to convey knowledge and present aspects of an archaeological site to a tourist. The user is encouraged to visit a site or view an artefact passively; to accept what they are shown as the final interpretation. Throughout this thesis I have challenged this limited usage and instead presented a unified approach to landscape archaeology that takes advantage of both computational and experiential analysis and combines them into a system that invites the user to take an *active* role in investigating the landscape. The embodied GIS is not a system that encourages mere consumption of data, instead it fosters the opportunity to question both the landscape being walked through, and the data that underlies the computational analysis.

I have shown the potential of a mixed reality application to transform the practice of landscape archaeology and bridge the middle ground and, in doing so, I have created a way in which we can view archaeological landscapes in a more nuanced and sometimes completely different light. We can now experiment with the experiential approach *in situ* but in such a way that the conditions of the experiments can be reproduced, shared and documented. As mixed reality techniques and technology improve, the breaks in presence will be reduced and the experience will become more seamless and more immersive. The system and concept as I have devised them can be used on any number of different archaeological sites, as it elegantly bridges the gap between a desk-bound GIS and a site-based body-centred study of the landscape. It is building on what we as archaeologists routinely do, but brings them together in an accessible and unique way. We can never reproduce exactly what it was like to be a Bronze Age person living and working on Leskernick Hill, but we can now provide a window onto that world, and use that window to play with different realities, weave different stories and, in doing so, will surely make new discoveries about the past.

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Appendix 1 - Code

```
/*
Camera Controller.cs
This script is for controlling cameras, I use this script
to control both the First-Person camera and also a remote
camera for creating fly-through animations or to allow
viewing of the data from a different location
*/

using UnityEngine;
using System.Collections;

public class cameraController : MonoBehaviour {

    GameObject _cameraFP = null;
    GameObject _cameraWV = null;

    void Start ()
    {
        // Initiate cameras
        _cameraFP = GameObject.Find("Main Camera");
        if (_cameraFP == null)
            Debug.Log("Start(): First Person Camera not found");

        _cameraWV = GameObject.Find("GoT camera");
        if (_cameraWV == null)
            Debug.Log("Start(): GoT camera not found");
        //run the sub-routine to select the actual camera
        //(default camera is camera 1)

        SelectCamera(1);
    }

    //sub-routine to select the camera
    void SelectCamera(int cameraIndex)
    {
        if (_cameraFP != null)
            _cameraFP.camera.enabled = (cameraIndex == 0);
        if (_cameraWV != null)
            _cameraWV.camera.enabled = (cameraIndex == 1);

    }
}

```

cameraGyro.js

```
/* cameraGyro.js */
#pragma strict
    // Gyroscope-controlled camera for iPhone & Android revised 2.26.12
    // This script has been adapted by Stuart Eve, for use in the Dead Men's Eyes system
    // Stereoskopix FOV2GO Copyright (c) 2011 Perry Hoberman
    // Perry Hoberman <hoberman@bway.net>
    //
    // Usage:
    // Attach this script to main camera.
    // Note: Unity Remote does not currently support gyroscope.
    // Use Landscape Left for correct orientation
    //
    // This script uses three techniques to get the correct orientation out of the gyroscope attitude:
    // 1. creates a parent transform (camParent) and rotates it with eulerAngles
    // 2. for Android (Samsung Galaxy Nexus) only: remaps gyro.Attitude quaternion values from xyzw to wxyz (quatMap)
    // 3. multiplies attitude quaternion by quaternion quatMult

    // Also creates a grandparent (camGrandparent) which can be rotated to change heading
    // This node allows an arbitrary heading to be added to the gyroscope reading
    // so that the virtual camera can be facing any direction in the scene, no matter which way the phone is actually facing
    // Option for touch input - horizontal swipe controls heading

    static var gyroBool : boolean;
    private var gyro : Gyroscope;
    private var quatMult : Quaternion;
    private var quatMap : Quaternion;
    // camera grandparent node to rotate heading
    private var camGrandparent : GameObject;
    private var heading : float = 0;
    private var headingUpDwn : float = 0;

    public var joystick : Joystick;

    // mouse/touch input
    public var touchRotatesHeading : boolean = true;
    private var screenSize : Vector2;
    private var mouseStartPoint: Vector2;
    private var headingAtTouchStart : float = 0;
    private var headingUpDwnAtTouchStart : float = 0;
    @script AddComponentMenu ("stereoskopix/s3d Gyro Cam")

    //GUI variables

    public var stringToEdit = "Hello World";

    function Awake() {
        // find the current parent of the camera's transform
        var currentParent = transform.parent;
        // instantiate a new transform
        var camParent = new GameObject ("camParent");
        // match the transform to the camera position
        camParent.transform.position = transform.position;
        // make the new transform the parent of the camera transform
        transform.parent = camParent.transform;
        // instantiate a new transform
        camGrandparent = new GameObject ("camGrandParent");
        // match the transform to the camera position
        camGrandparent.transform.position = transform.position;
        // make the new transform the grandparent of the camera transform
        camParent.transform.parent = camGrandparent.transform;
        // make the original parent the great grandparent of the camera transform
        camGrandparent.transform.parent = currentParent;

```

```
        // check whether device supports gyroscope
        #if UNITY_3_4
        gyroBool = Input.isGyroAvailable;
        #endif
        #if UNITY_3_5
        gyroBool = SystemInfo.supportsGyroscope;
        #endif

        if (gyroBool) {
            gyro = Input.gyro;
            gyro.enabled = true;
            #if UNITY_IPHONE
                camParent.transform.eulerAngles = Vector3(90,90,0);
                if (Screen.orientation == ScreenOrientation.LandscapeLeft) {
                    quatMult = Quaternion(0,0,0.7071,0.7071);
                } else if (Screen.orientation == ScreenOrientation.LandscapeRight) {
                    quatMult = Quaternion(0,0,-0.7071,0.7071);
                } else if (Screen.orientation == ScreenOrientation.Portrait) {
                    quatMult = Quaternion(0,0,1,0);
                } else if (Screen.orientation == ScreenOrientation.PortraitUpsideDown) {
                    quatMult = Quaternion(0,0,0,1);
                }
            #endif
            #if UNITY_ANDROID
                camParent.transform.eulerAngles = Vector3(-90,0,0);
                if (Screen.orientation == ScreenOrientation.LandscapeLeft) {
                    quatMult = Quaternion(0,0,0.7071,-0.7071);
                } else if (Screen.orientation == ScreenOrientation.LandscapeRight) {
                    quatMult = Quaternion(0,0,-0.7071,-0.7071);
                } else if (Screen.orientation == ScreenOrientation.Portrait) {
                    quatMult = Quaternion(0,0,0,1);
                } else if (Screen.orientation == ScreenOrientation.PortraitUpsideDown) {
                    quatMult = Quaternion(0,0,1,0);
                }
            #endif
            Screen.sleepTimeout = SleepTimeout.NeverSleep;
        } else {
            #if UNITY_EDITOR
                //print("NO GYRO");
            #endif
        }
    }

    function Start() {
        screenSize.x = Screen.width;
        screenSize.y = Screen.height;
    }

    function Update () {
        if (gyroBool) {
            #if UNITY_IPHONE
                quatMap = gyro.attitude;
            #endif
            #if UNITY_ANDROID
                quatMap =
Quaternion(gyro.attitude.w,gyro.attitude.x,gyro.attitude.y,gyro.attitude.z);
            #endif
            transform.localRotation = quatMap * quatMult;
        }
        #if (UNITY_IPHONE || UNITY_ANDROID) && !UNITY_EDITOR
            if (touchRotatesHeading) {
                GetTouchMouseInput();
            }
            camGrandparent.transform.localEulerAngles.y = heading;
            camGrandparent.transform.localEulerAngles.z = headingUpDwn;
        #endif
```

```

        if (joystick.position.x > 0 || joystick.position.x < 0) {
            camGrandparent.transform.position.z += joystick.position.x;
        };

        if (joystick.position.y > 0 || joystick.position.y < 0) {
            camGrandparent.transform.position.x += joystick.position.y;
        };

    }

    function GetTouchMouseInput() {
        if(Input.GetMouseButtonDown(0)) {
            mouseStartPoint = Input.mousePosition;
            headingAtTouchStart = heading;
            headingUpDwnAtTouchStart = headingUpDwn;
        } else if (Input.GetMouseButton(0)) {
            var delta : Vector2;
            var mousePos = Input.mousePosition;
            delta.x = (mousePos.x - mouseStartPoint.x)/screenSize.x;
            delta.y = (mousePos.y - mouseStartPoint.y)/screenSize.y;
            heading = (headingAtTouchStart+delta.x*100);
            heading = heading%360;
            headingUpDwn = (headingUpDwnAtTouchStart+delta.y*100);
            headingUpDwn = headingUpDwn%360;
        }
    }
```

chooseHut.js

```
/*
chooseHut.js
This script is used by the database system ARK (ark.lparchaeology.com) to automatically display the 3d model
and location of a chosen house.
It takes a URL from the ARK database and then splits that URL to identify the house number that is required,
it then matches that with the correct house attribute in Unity and moves the virtual camera to the correct
location
*/
#pragma strict

function Start () {

    //we need to get the hut id - so we can choose the right camera to start from
    Debug.Log("SRC: " + Application.srcValue);
    //this gives us the src value - which we can now explode and parse
    //first explode on the '?' to get the start of the params
    var src = Application.srcValue;
    // an example src = "data/unity_projects/leskernick.unity3d/leskernick.unity3d?item_key=hut_cd&hut_cd=LK12_28";
    var splitsrc = src.Split('?'[0]);

    // iterate through the array - we should be in the querystring now
     for (var value : String in splitsrc) {
         var splitparam = value.Split('&'[0]);
         for (var param : String in splitparam) {
             var splitparam2 = param.Split('='[0]);
             if (splitparam2[0] == 'hut_cd') {
                 var id = splitparam2[1];
                 var split_id = id.Split('_'[0]);
                 SelectHut(parseInt(split_id[1]));
             };
         }
     }
}

function Update () {

}

var hut : GameObject;
var player : GameObject;

//find the house and move the player (i.e. the first person camera) to its location
function SelectHut (index : int) {
    hut = GameObject.Find("hut_" + index);
    Debug.Log(hut);
    player.transform.position = hut.transform.position;
}


```

```
/*Clipped.shader
* When attached to a render object this shader
* will cause the object to be occluded by any
* other render object that has the TransWall
* shader attached to it.
*/
Shader "Clipped" {
    Properties {
        _MainTex ("Base (RGB)", 2D) = "white" {}
    }
    SubShader {
        Tags { "RenderType"="Opaque" "Queue" = "Geometry+2" }
        LOD 200

        CGPROGRAM
        #pragma surface surf Lambert

        sampler2D _MainTex;

        struct Input {
            float2 uv_MainTex;
        };

        void surf (Input IN, inout SurfaceOutput o) {
            half4 c = tex2D (_MainTex, IN.uv_MainTex);
            o.Albedo = c.rgb;
            o.Alpha = c.a;
        }
        ENDCG
    }
    FallBack "Diffuse"
}

```

```
/*
convertToBng.cs
This script is used to convert GPS coordinates
from the WGS84 geographic projection (LatLongs) into
the OSGB36 British National Grid map projection.

It can also be used to convert from BNG into Unity
gamespace coordinates by using a false Easting and Northing

This script is used to automatically update the virtual
position of the AR device from the real reality (GPS) position

It also builds the Graphical User Interface for the Location-Based
AR application
*/
using UnityEngine;
using System.Collections;

[System.Serializable]
public class MapCoordinate {
    public float latitude;
    public float longitude;
    public float altitude;
    public float heading;

    public float x {
        get {
            return longitude;
        }

        set {
            longitude = value;
        }
    }

    public float y {
        get {
            return latitude;
        }

        set {
            latitude = value;
        }
    }

    public float z {
        get {
            return altitude;
        }

        set {
            altitude = value;
        }
    }

    public float direction {
        get {
            return heading;
        }

        set {
            heading = value;
        }
    }

    public MapCoordinate(float lon, float lat, float alt, float dir) {
```

```
        longitude = lon;
        latitude = lat;
        altitude = alt;
        direction = dir;
    }
}

public class convertToBNG : MonoBehaviour {

    public float gpsAccuracy = 5;
    public float gpsUpdateDistance = 1;
    public float falseEasting = 212500;
    public float falseNorthing = 75000;
    private GameObject GyroCam;
    bool gpsRunning = false;
    private bool ready = false;
    public MapCoordinate globalPos;
    public MapCoordinate prevGlobalPos;
    public MapCoordinate BNGPos;

    private float BNG_E;
    private float BNG_N;
    private float BNG_alt;
    private float refresh_time = 2.0f;

    //GUI Variables
    private string BNG_E_input = "218178";
    private string BNG_N_input = "80101.90";
    private string BNG_alt_input = "292";
    private string BNG_heading_input = "180";

    public Shader diffuse = Shader.Find("Diffuse");
    public Shader transwalls = Shader.Find("TransWalls");
    public GameObject landscape = GameObject.Find("blender_dtm_10k_lores");

    public GameObject huts = GameObject.Find("huts");
    public GameObject spheres = GameObject.Find("spheres");


    void Awake() {
        prevGlobalPos = new MapCoordinate(0,0,0,0);
        globalPos = new MapCoordinate(0,0,0,0);
        BNGPos = new MapCoordinate(0,0,0,0);
    }

    // Use this for initialization
    void Start () {

        StartGPS();
        LatLongToEastNorth(globalPos.latitude, globalPos.longitude, globalPos.altitude, true);


    }

    // Update is called once per frame
    void Update () {

    }
    private double toRad(double val)
    {
        return val * (System.Math.PI / 180);
    }

    public void LatLongToEastNorth(double latitude, double longitude, double altitude, bool move_camera = false)
    {
```

```
            //This will not work unless you have your lats and longs in decimal degrees.
            latitude = toRad(latitude);
            longitude = toRad(longitude);

            double a = 6377563.396, b = 6356256.910; // Airy 1830 major &amp; minor semi-axes
            //double a = 6378137.0, b = 6356752.314245; WGS84 major &amp; minor semi-axes

            double F0 = 0.9996012717; // NatGrid scale factor on central meridian
            double lat0 = toRad(49);
            double lon0 = toRad(-2); // NatGrid true origin
            double N0 = -100000, E0 = 400000; // northing &amp; easting of true origin, metres
            double e2 = 1 - (b * b) / (a * a); // eccentricity squared
            double n = (a - b) / (a + b), n2 = n * n, n3 = n * n * n;

            double cosLat = System.Math.Cos(latitude), sinLat = System.Math.Sin(latitude);
            double nu = a * F0 / System.Math.Sqrt(1 - e2 * sinLat * sinLat) ; // transverse radius of curvature
            double rho = a * F0 * (1 - e2) / System.Math.Pow(1 - e2 * sinLat * sinLat, 1.5); // meridional radius of curvature

            double eta2 = nu / rho - 1;

            double Ma = (1 + n + (5 / 4) * n2 + (5 / 4) * n3) * (latitude - lat0);
            double Mb = (3 * n + 3 * n * n + (21/8)*n3) * System.Math.Sin(latitude - lat0) * System.Math.Cos(latitude + lat0);
            double Mc = ((15/8)*n2 + (15/8)*n3) * System.Math.Sin(2 * (latitude - lat0)) * Svstem.Math.Cos(2 * (latitude + lat0));
            double Md = (35 / 24) * n3 * System.Math.Sin(3 * (latitude - lat0)) * Svstem.Math.Cos(3 * (latitude + lat0));
            double M = b * F0 * (Ma - Mb + Mc - Md); // meridional arc

            double cos3lat = cosLat * cosLat * cosLat;
            double cos5lat = cos3lat * cosLat * cosLat;
            double tan2lat = System.Math.Tan(latitude) * System.Math.Tan(latitude);
            double tan4lat = tan2lat * tan2lat;

            double I = M + N0;
            double II = (nu / 2) * sinLat * cosLat;
            double III = (nu / 24) * sinLat * cos3lat * (5 - tan2lat + 9 * eta2);
            double IIIA = (nu / 720) * sinLat * cos5lat * (61 - 58 * tan2lat + tan4lat);
            double IV = nu * cosLat;
            double V = (nu / 6) * cos3lat * (nu / rho - tan2lat);
            double VI = (nu / 120) * cos5lat * (5 - 18 * tan2lat + tan4lat + 14 * eta2 - 58 * tan2lat * eta2);

            double dLon = longitude - lon0;
            double dLon2 = dLon * dLon, dLon3 = dLon2 * dLon, dLon4 = dLon3 * dLon, dLon5 = dLon4 * dLon, dLon6 = dLon5 * dLon;

            double N = I + II * dLon2 + III * dLon4 + IIIA * dLon6; //This is the northing
            double E = E0 + IV * dLon + V * dLon3 + VI * dLon5; //This is the easting
            BNGPos.x = (float)E;
            BNGPos.z = (float)N;
            BNGPos.y = (float)altitude;
            Debug.Log("BNG E: " + E + " BNG N: " + N + " Alt: " + altitude);
            if (move_camera) {
                MoveCameraToGameSpace(E, N, altitude);
            }

        }

    public void MoveCameraToGameSpace(double raw_BNG_E, double raw_BNG_N, double raw BNG_alt, double heading = 9999.99){
        GyroCam = GameObject.Find("camGrandParent");
```

```
            Debug.Log("I should be moving");
            //now put the GyroCamera into the right place
            BNG_E = (float)raw_BNG_E - falseEasting;
            BNG_N = (float)raw_BNG_N - falseNorthing;
            BNG_alt = (float)raw_BNG_alt;
            //Vector3 pos = new Vector3(BNG_E, BNG_alt, BNG_N);
            GyroCam.transform.position = new Vector3(BNG_E, BNG_alt, BNG_N);
            if (heading != 9999.9) {
                GyroCam.transform.localEulerAngles = new Vector3(0.0f, (float)heading, 0.0f);

            } else {
                GyroCam.transform.localEulerAngles = new Vector3(0.0f, 0.0f, 0.0f);
            }
        }

        IEnumerator ActivateGPS() {
            gpsRunning = true;
            Input.location.Start(gpsAccuracy, gpsUpdateDistance);

            float duration = 0;
            while (duration < 20.0f) {
                if (Input.location.status == LocationServiceStatus.Running
                    || Input.location.status == LocationServiceStatus.Failed) break;
                yield return new WaitForSeconds(0.1f);

                duration += 0.1f;
            }

            if (duration >= 20.0f) {
                Debug.Log("**** LocationService Timed out");
            }

            if (Input.location.status == LocationServiceStatus.Failed) {
                Debug.Log("**** User declined LocationService?");
                gpsRunning = false;
            }

            ready = true;
            Input.compass.enabled = true;

            while (Input.location.status == LocationServiceStatus.Running) {
                globalPos.longitude = Input.location.lastData.longitude;
                globalPos.latitude = Input.location.lastData.latitude;
                globalPos.altitude = Input.location.lastData.altitude;
                //Debug.Log("Lat:" + globalPos.latitude + " Lon: " + globalPos.longitude + " Alt: " + globalPos.altitude);
                LatLongToEastNorth(globalPos.latitude, globalPos.longitude, globalPos.altitude);
                /*
                if (globalPos.x != prevGlobalPos.x
                    || globalPos.y != prevGlobalPos.y) Debug.Log("iphone gps: (" + globalPos.x + "," + globalPos.y + ")");
                */

                yield return new WaitForSeconds(refresh_time);
            }

            gpsRunning = false;
        }

        public void StartGPS() {
            if (Application.isEditor) {
                ready = true;
                return;
            }
```

```
            if (!gpsRunning) StartCoroutine(ActivateGPS());
        }

        public void OnGUI() {
            BNG_E_input = GUI.TextField(new Rect(10, 10, 200, 20),BNG_E_input, 50);
            BNG_N_input = GUI.TextField(new Rect(10, 40, 200, 20),BNG_N_input, 50);
            BNG_alt_input = GUI.TextField(new Rect(10, 70, 200, 20),BNG_alt_input, 50);
            BNG_heading_input = GUI.TextField(new Rect(10, 110, 200, 20),BNG_heading_input, 50);

            if (GUI.Button (new Rect (10,140,300,100), "Reset Position and Heading")) {
                MoveCameraToGameSpace(double.Parse(BNG_E_input), double.Parse(BNG_N_input), double.Parse(BNG_alt_input), double.Parse(BNG_heading_input));
            }

            if (GUI.Button (new Rect (10,240,300,100), "Show/Hide Landscape")) {
                if (landscape.renderer.material.shader == diffuse)
                        landscape.renderer.material.shader = transwalls;
                    else
                        landscape.renderer.material.shader = diffuse;
            }
            if (GUI.Button (new Rect (10,450,300,100), "Set position via GPS")) {
                LatLongToEastNorth(globalPos.latitude, globalPos.longitude, globalPos.altitude, false);
                BNG_E_input = GUI.TextField(new Rect(10, 10, 200, 20),"" + BNGPos.x, 50);
                BNG_N_input = GUI.TextField(new Rect(10, 40, 200, 20),"" + BNGPos.z, 50);
                BNG_alt_input = GUI.TextField(new Rect(10, 70, 200, 20),"" + BNGPos.y, 50);
            }

            //now put in the buttons for the test scenarios
            if (GUI.Button (new Rect (1350,140,50,50), "Test 1")) {
                huts.SetActiveRecursively(false);
                spheres.SetActiveRecursively(false);
            }
            if (GUI.Button (new Rect (1350,210,50,50), "Test 2")) {
                huts.SetActiveRecursively(false);
                spheres.SetActiveRecursively(true);
            }
            if (GUI.Button (new Rect (1350,280,50,50), "Test 3")) {
                huts.SetActiveRecursively(true);
                spheres.SetActiveRecursively(false);
            }
        }

    }
```

deadMansNose.pde

```
/*
  Dead Man's Nose

 A simple web server that fires a digital fan
 using a WiFi shield.

 This script is adapted by Stuart Eve from:

 This example is written for a network using WPA encryption. For
 WEP or WPA, change the Wifi.begin() call accordingly.

 Circuit:
 * WiFi shield attached
 * Analog inputs attached to pins A0 through A5 (optional)

 created 13 July 2010
 by dlf (Metodo2 srl)
 modified 31 May 2012
 by Tom Igoe
 */
#include <SPI.h>
#include <WiFi.h>

//Servo myservo;  // create servo object to control a servo
                // a maximum of eight servo objects can be created

//int pos = 0;    // variable to store the servo position


char ssid[] = "*******"; //  your network SSID (name)
char pass[] = "*******";    // your network password (use for WPA, or use as key for WEP)
int keyIndex = 0;                 // your network key Index number (needed only for WEP)

int status = WL_IDLE_STATUS;

WiFiServer server(80);

int fanPin = 9;
boolean fanIsOn = 0;

String currentLine = "";
String reqPin = "";
String power = "";


void setup() {
  // reserve space for the strings:
  currentLine.reserve(256);
  //Initialize serial and wait for port to open:
  Serial.begin(9600);
  while (!Serial) {
    ; // wait for serial port to connect. Needed for Leonardo only
  }

  // check for the presence of the shield:
  if (WiFi.status() == WL_NO_SHIELD) {
    Serial.println("WiFi shield not present");
    // don't continue:
    while(true);
  }

  // attempt to connect to Wifi network:
  while ( status != WL_CONNECTED) {
    Serial.print("Attempting to connect to SSID: ");
    Serial.println(ssid);
    // Connect to WPA/WPA2 network. Change this line if using open or WEP network:
```

```
      status = WiFi.begin(ssid, pass);

      // wait 10 seconds for connection:
      delay(10000);
    }
    server.begin();
    // you're connected now, so print out the status:
    printWifiStatus();
    digitalWrite(2, HIGH);

    //myservo.attach(9);  // attaches the servo on pin 9 to the servo object

  }


  void loop() {
    // listen for incoming clients
    WiFiClient client = server.available();
    if (client) {
      Serial.println("new client");
      if (fanIsOn == 0){
       //   analogWrite(fanPin,250);
          fanIsOn = 1;
      } else {
        //  analogWrite(fanPin,150);
          fanIsOn = 0;
      }
      // an http request ends with a blank line
      boolean currentLineIsBlank = true;

      int charcounter = 0;
      while (client.connected()) {
        if (client.available()) {
         char c = client.read();
         // add incoming byte to end of line:
          currentLine += c;
          // if you've gotten to the end of the line (received a newline
          // character) and the line is blank, the http request has ended,
          // so you can send a reply
          if (c == '\n' && currentLineIsBlank) {
            // send a standard http response header
            client.println("HTTP/1.1 200 OK");
            client.println("Content-Type: text/html");
            client.println("Connnection: close");
            client.println();
            client.println("<!DOCTYPE HTML>");
            client.println("<html>");
            // add a meta refresh tag, so the browser pulls again every 5 seconds:
           // client.println("<meta http-equiv=\"refresh\" content=\"5\">");
            // output the value of each analog input pin
            for (int analogChannel = 0; analogChannel < 6; analogChannel++) {
              int sensorReading = analogRead(analogChannel);
              client.print("analog input ");
              client.print(analogChannel);
              client.print(" is ");
              client.print(sensorReading);
              client.println("<br />");
            }
            client.println("</html>");
             break;
          }
          if (c == '\n') {
            // you're starting a new line
            currentLineIsBlank = true;
            //check to see if this line is the GET request
            if (currentLine.startsWith("GET")) {
```

```
            Serial.println(currentLine);
            reqPin = String(currentLine[10]) + String(currentLine[11]);
            Serial.println("Pin Req = " + reqPin);
            power = String(currentLine[19]) + String(currentLine[20]) + String(currentLine[21]);
            Serial.println("Power = " + power);
          }

          currentLine = "";
        }
        else if (c != '\r') {
          // you've gotten a character on the current line
          currentLineIsBlank = false;
        }
      }
    }
    digitalWrite(reqPin.toInt(), HIGH);
    delay(5000);
    digitalWrite(reqPin.toInt(), LOW);
    delay(25);
    // give the web browser time to receive the data
    delay(1);
      // close the connection:
      client.stop();
      Serial.println("client disonnected");
  }
}


void printWifiStatus() {
  // print the SSID of the network you're attached to:
  Serial.print("SSID: ");
  Serial.println(WiFi.SSID());

  // print your WiFi shield's IP address:
  IPAddress ip = WiFi.localIP();
  Serial.print("IP Address: ");
  Serial.println(ip);

  // print the received signal strength:
  long rssi = WiFi.RSSI();
  Serial.print("signal strength (RSSI):");
  Serial.print(rssi);
  Serial.println(" dBm");
}
```

drawGISLine.cs

```
/*
drawGISLine.cs
This script creates 3D lines from a file extracted by
the GRASS GIS function v.out.ascii to represent GIS
polyline data within Unity
The ASCII file can be exported on-demand to allow
virtually real-time access to the GIS data

*/

using UnityEngine;
using System.Collections;

//use the Vectrosity library to create the 3D tubes
using Vectrosity;

public class drawGISLine : MonoBehaviour {

    public TextAsset coord_file = new TextAsset();
    public float false_easting = new float();
    public float false_northing = new float();
    public float drop_height = new float();

    // Use this for initialization
    void Start () {
        bool new_line = false;
        //each ASCII file created by GRASS v.out.ascii is a standard format
        //the first thing we need to do is get an array filled with the different line elements within the ascii file
        string[] dataLines = coord_file.text.Split('\n');
        string[] dataPairs = new string[dataLines.Length];

        //note we have set this to start at line 10 as that begins after the standard ASCII header
        int lineNum = 0;
        for (int key = 0; key < dataLines.Length; ++key) {
            if (key > 9) {
                dataPairs[lineNum++] = dataLines[key];
            }
        }
        //create two Array holders to hold the collections of lines
        //these will be filled with coordinate pairs which make up the lines
        //once filled the arrays will be looped through to actual render the
        //lines themselves
        ArrayList lines = new ArrayList();
        ArrayList line = new ArrayList();

        bool new_line_bool = true;

        int i = 0;

        //loops through each coordinate pair (a line is made up of a set of coordinate pairs)
        //each Line in the ASCII file starts with an 'L' therefore each line can be identified

        foreach (string pair in dataPairs) {
            if (pair != null) {
                if (pair.Contains("L")) {
                    new_line_bool = true;
                } else {
                    string[] coords = pair.Split(' ');
                    ArrayList coord_clean = new ArrayList();

                    foreach (string coord in coords ) {
                        if (coord != "") {
```

```
                            coord_clean.Add(float.Parse(coord));
                        }
                    }
                    //check after cleaning we have exactly 2 coordinates
                    //then apply the false easting and northings to align them from real
                    //world coordinates into the Unity gamespace
                    if (coord_clean.Count == 2) {
                        float easting = (float)coord_clean[0] - false_easting;
                        float northing = (float)coord_clean[1] - false_northing;


                        //check they are valid coordinates if so either add them to a
                        //line or use them to start a new line
                        if (easting > 0 && northing > 0) {
                            if (new_line_bool == true) {
                                if (line.Count>1) {
                                    lines.Add(line.Clone());
                                }
                                line.Clear();
                                line.Add(new Vector3(easting,drop_height,northing));
                                new_line_bool = false;
                            } else {
                                line.Add(new Vector3(easting,drop_height,northing));
                            }
                        }
                    }
                }

            }
        }
        //once the line array is created - actually go through and draw the lines in Unity
        foreach (ArrayList line_seg in lines) {
            Vector3[] linePoints = new Vector3[line_seg.Count];
            int j = 0;
            foreach (Vector3 line_vec in line_seg) {
              linePoints[j] = line_vec;
              j++;
            }
            VectorLine myLine = new VectorLine("MyLine", linePoints, Color.red, null, 1.0f.LineType.Continuous);
            myLine.Draw3D();
        }
    }

    // Update is called once per frame
    void Update () {

    }
}

```

OccludableAudio.cs

```
/*
OccludableAudio.cs
This script creates an audio source that is occluded by the geometry
within the scene.
This script should be attached to an audio source and the Listener
variable assigned to the player.
*/
using UnityEngine;
using System.Collections;

public class OccludableAudio : MonoBehaviour {

    private Transform m_MyTrans;
    private AudioSource m_Source;

    private float m_MaxDistance;

    //set the level of occlusion (distance and fade)

    public Transform Listener;
    public float OccludedDistance = 5.0f;
    public float FadeSpeed = 10.0f;
    public LayerMask Mask;

    void Start(){
        m_MyTrans = transform;
        m_Source = audio;
        m_MaxDistance = m_Source.maxDistance;
    }
    void Update(){
        float target;
        //use the physics engine to raycast to the nearest occluding geometry
        if (Physics.Linecast(Listener.position, m_MyTrans.position, Mask.value)){
            target = OccludedDistance;
        } else{
            target = m_MaxDistance;
        }
        //fade the audio if necessary
        m_Source.maxDistance = Mathf.MoveTowards(m_Source.maxDistance, target, Time.deltaTime * FadeSpeed);
        Debug.Log("maxdistance: " + m_Source.maxDistance);
    }
}
```

placeHuts.js

```
/*
placeHuts.js
This script creates 3D points from a file extracted by
the GRASS GIS function v.out.ascii to represent GIS
point data within Unity
The ASCII file can be exported on-demand to allow
virtually real-time access to the GIS data
*/
#pragma downcast
var coord_file : TextAsset;
var false_easting : float;
var false_northing : float;
var drop_height : float;
var hut : Transform;
var prefix : String = 'hut';
var player : GameObject;

function Start () {

    //read in the object locations from the ascii file
    var returnChar = "\n"[0];
    var commaChar = "|"[0];

    //parse the file extracting the coordinate pairs

    var dataLines = coord_file.text.Split(returnChar);
    var buildDataPairs = new ArrayList();

    for (var dataLine in dataLines) {
        var dataPair = dataLine.Split(commaChar);
        buildDataPairs.Add(dataPair);
    }
    //put the coordinate pairs into an array and apply the false Easting
    //and Northings
    var dataPairs = buildDataPairs.ToArray();
    for (var i=0; i < dataPairs.length - 1; i++) {
        var easting = parseFloat(dataPairs[i][0]) - false_easting;
        var northing = parseFloat(dataPairs[i][1]) - false_northing;
        //in order for the 3D models to align properly with the landscape, they need
        //to be 'dropped' from a small height and their physics colliders take care of the
        //rest. Therefore place the model a little way above the 'ground' and then instantiate
        //it. As soon as it hits the ground its rotation is frozen.
        var hit : RaycastHit;
        if (Physics.Raycast (Vector3(easting, drop_height, northing), -Vector3.up, hit, 100.0)) {
            var distanceToGround = hit.point.y + 5;
        }
        var newhut = Instantiate (hut, Vector3(easting, distanceToGround, northing), Quaternion.identity);
        //finally name the model by using the attributes in the GIS ascii file
        newhut.name = prefix + "_" + dataPairs[i][2];

    };
}

function Update () {

}
```

```
/*
smellyFan.js
This script is used by the Dead Men's Nose Arduino
application. When the player reaches a certain
area in the Unity/AR world (a smellzone) - a
signal is sent to the webpage interface that
controls the Arduino microcontroller. The webpage is
sent an instruction via the querystring, to tell it
which pin to send power to. This then starts the
fan - which in turn wafts the approriate smell
from the Dead Man's Nose.
*/
#pragma strict

// Fire off Arduino pins
public var url = "http://192.168.0.4/?pin=";
public var smell1 = "09";
public var smell2 = "10";
function Start () {
    url = url + smell1;
     // Start a download of the given URL
    var www : WWW = new WWW (url);

    // Wait for download to complete
    yield www;

}
```

TransWalls.shader

```
/*
* Transwalls.shader
* Any render object that has this shader
* attached will occlude any part of
* another object that has the Clipped
* shader attached to it
*
*/
Shader "TransWalls" {

    SubShader{
        Tags {"Queue" = "Geometry+1"}
        ColorMask 0
        Pass{}
    }

}

```

Appendix 2 - Gazetteer

P1

Photo Location

Number indicates photo number

Wedge indicates direction of photo

Panorama Photo Location

Bronze Age Houses

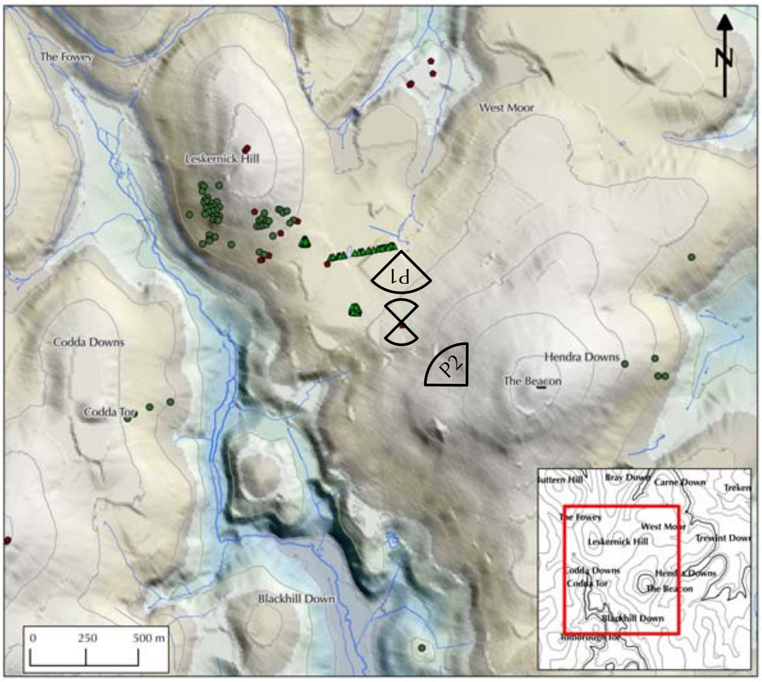
Stone Row and Stone Circles

Cairns

Beacon Mound

P1

P2

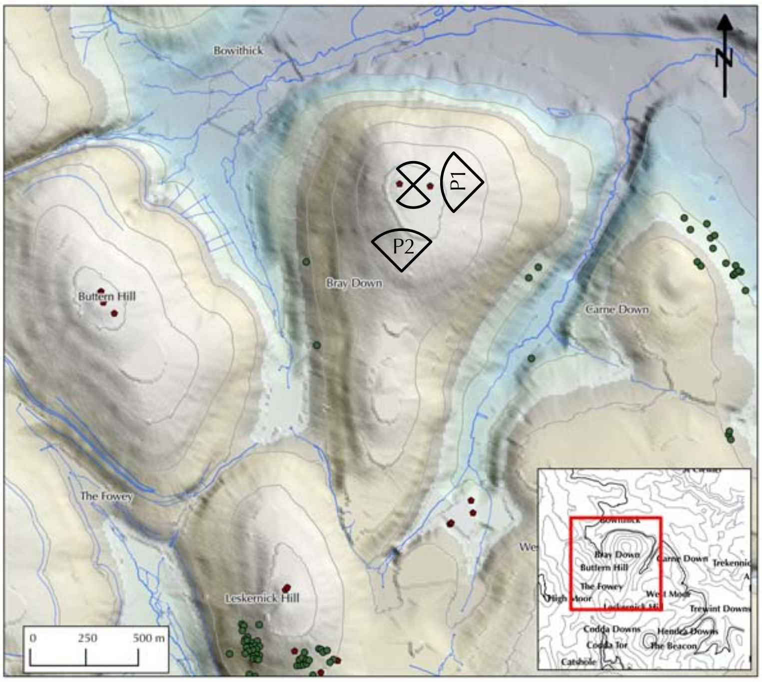


N

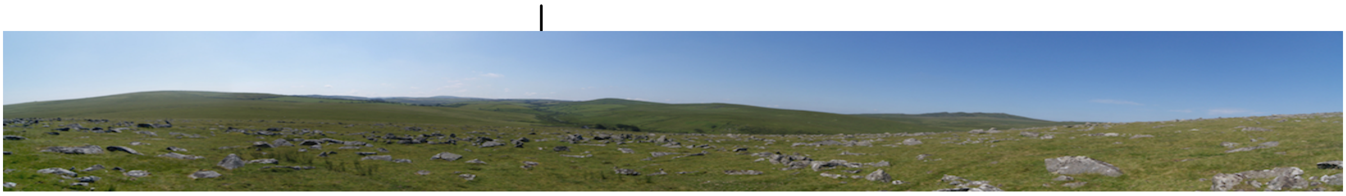
Bray Down

P1

P2



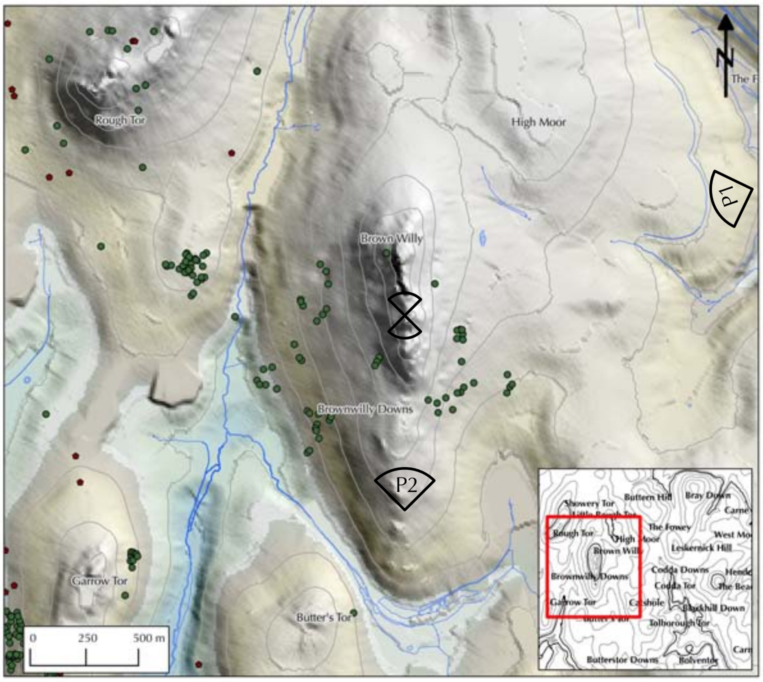
S



Brown Willy

P1

P2

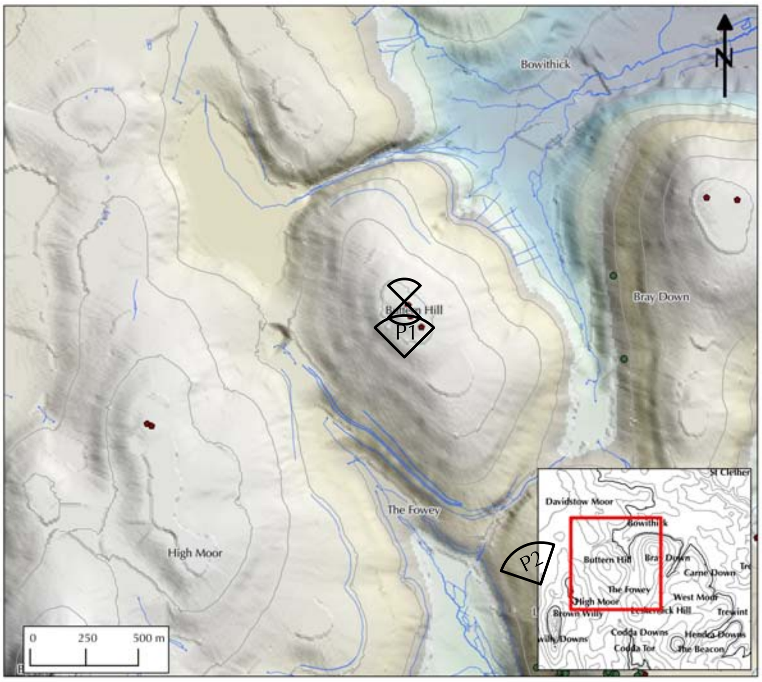


N

Buttern Hill

P1

P2

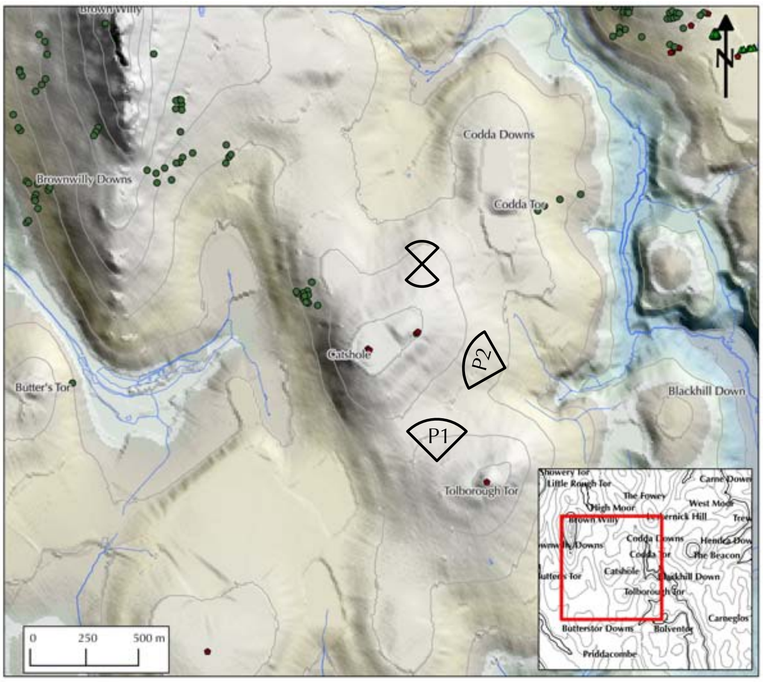


N

Catshole Tor

P1

P2

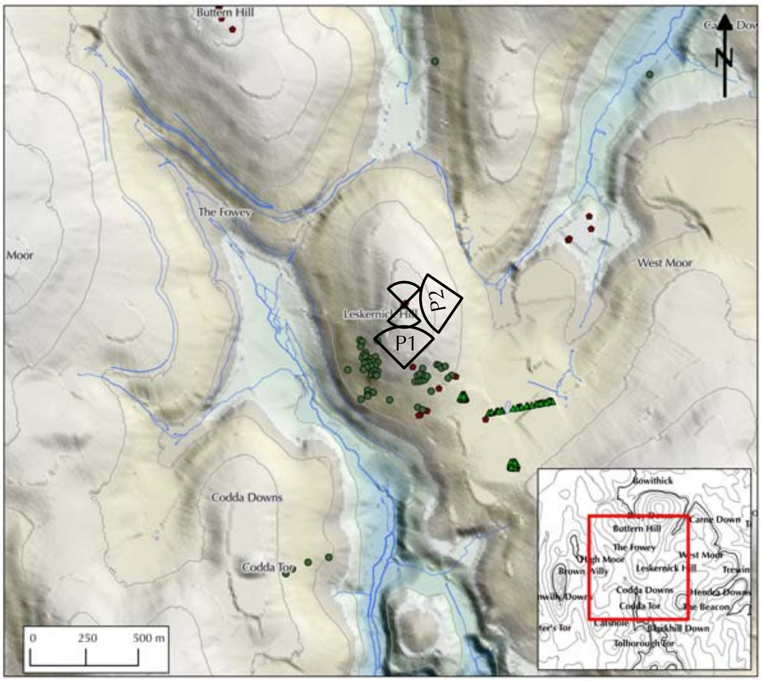


N

The Great Cairn

P1

P2

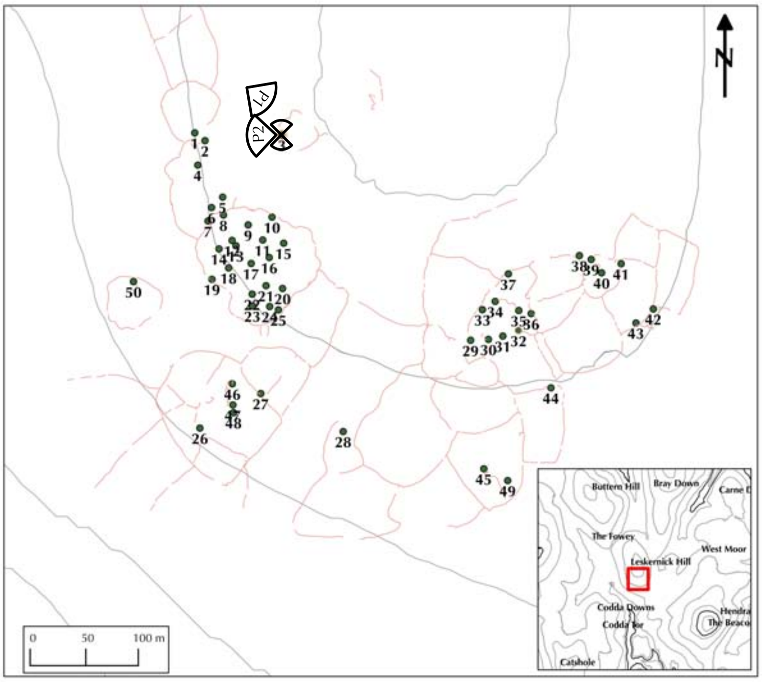


N

House 3 (Shaman's House)

P1

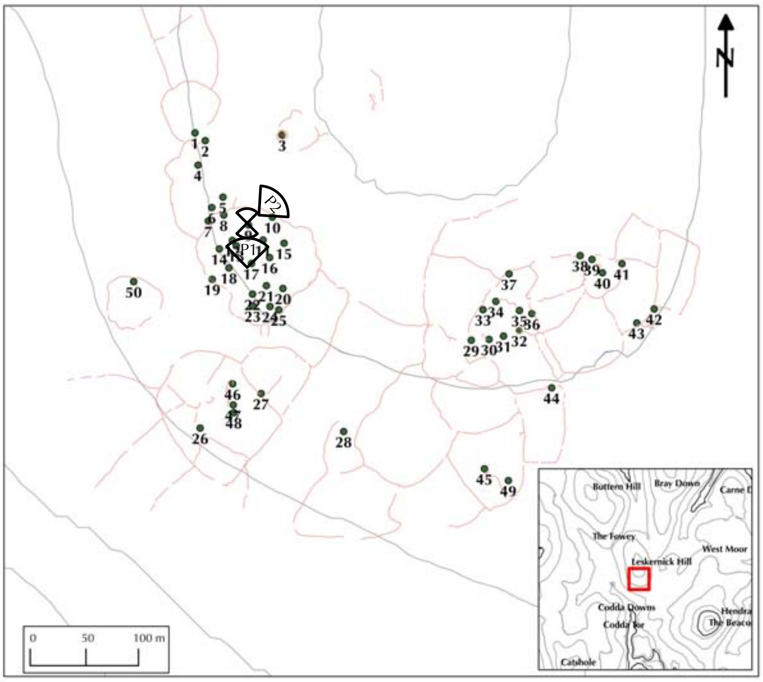
P2



House 9

P1

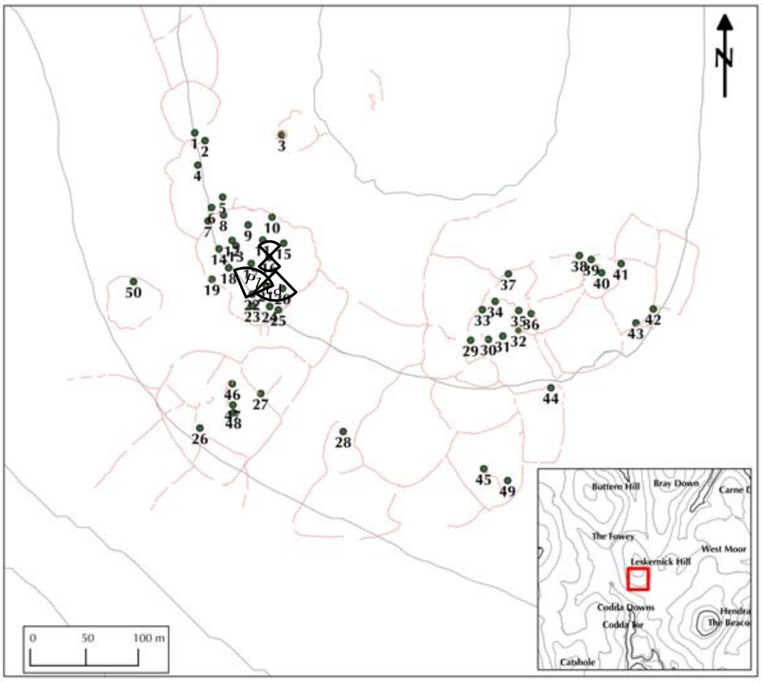
P2



House 16

P1

P2

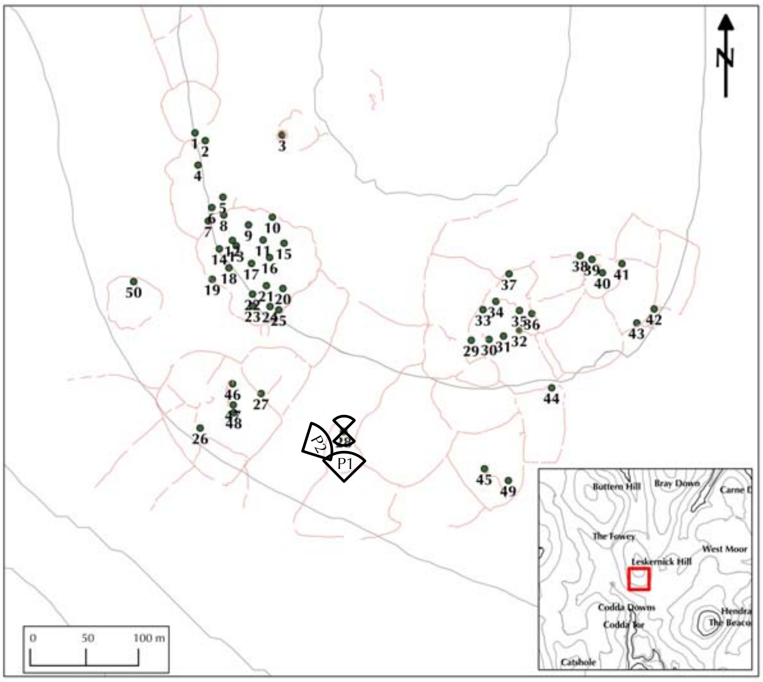


N

House 28 (Shaman's House)

P1

P2

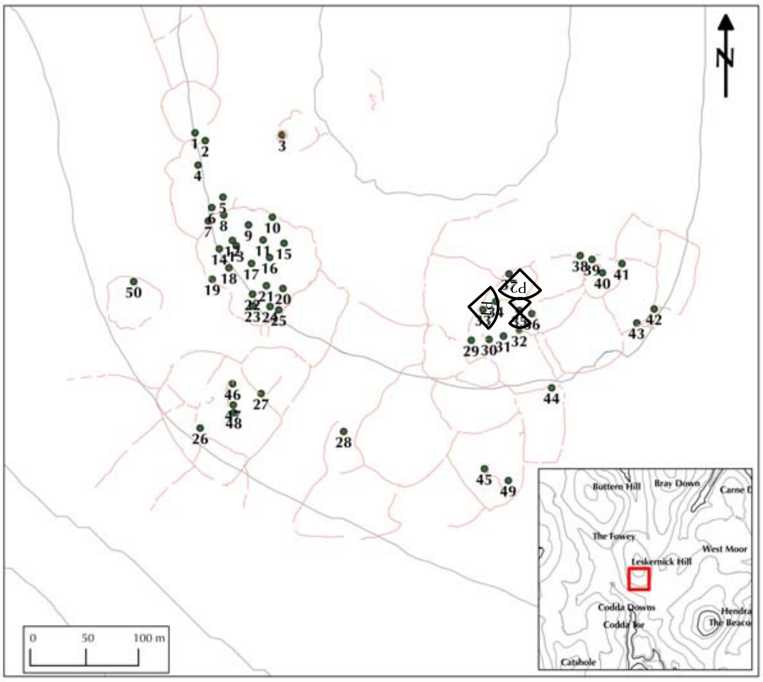


N

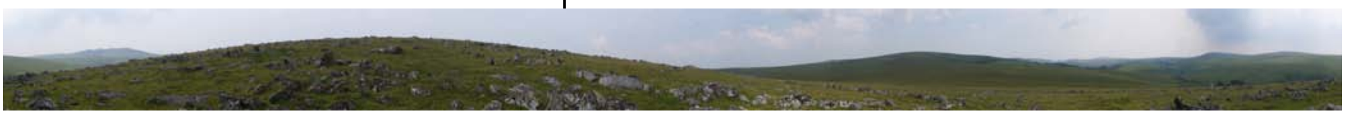
House 35

P1

P2



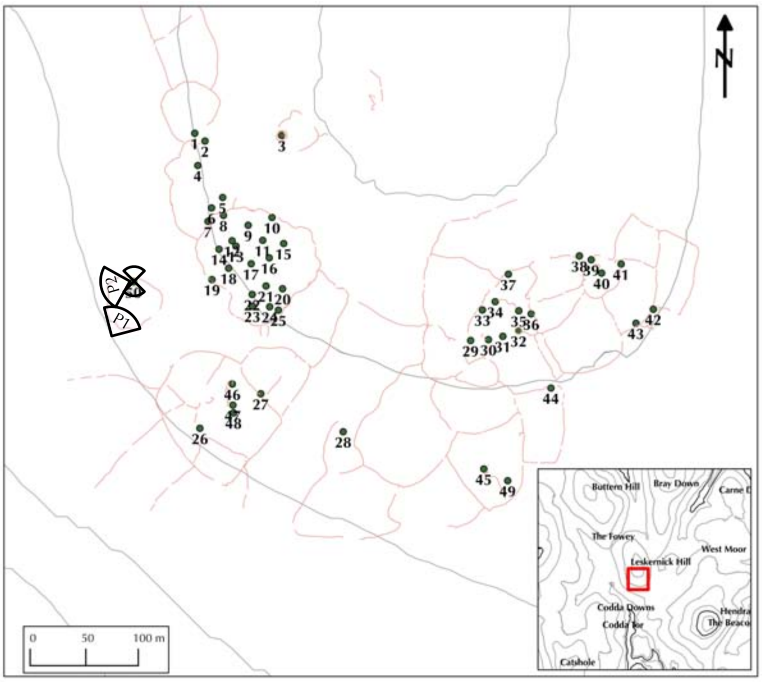
N



House 50

P1

P2

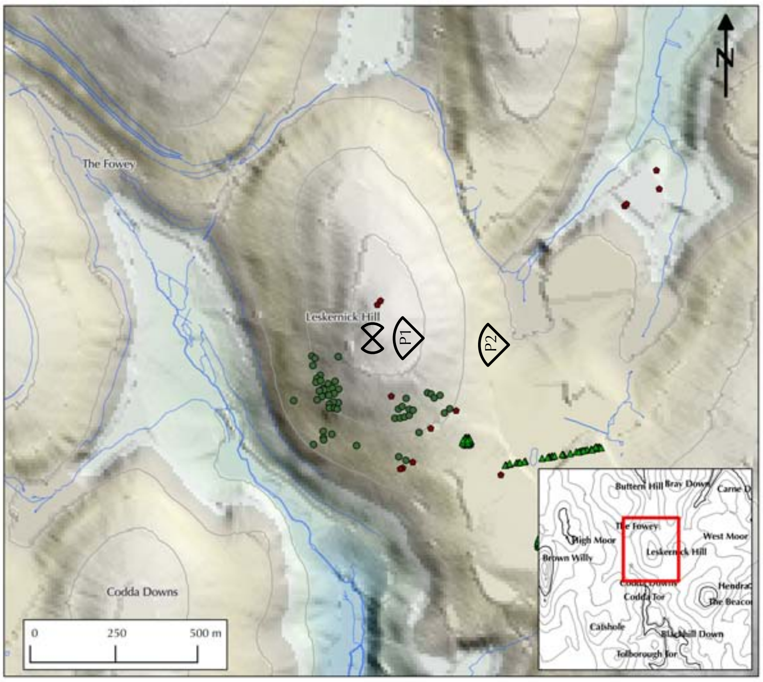


N

The Propped Stone/Quoit

P1

P2

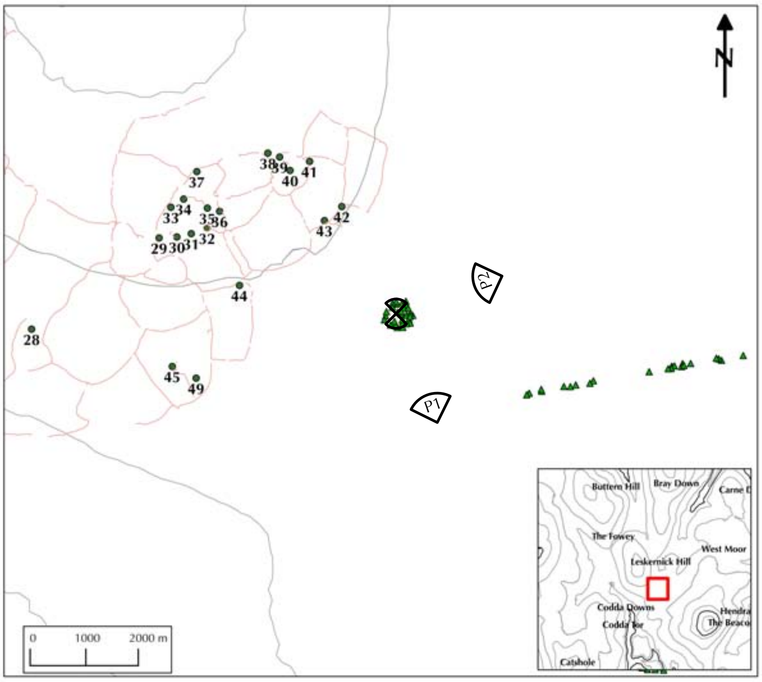


N

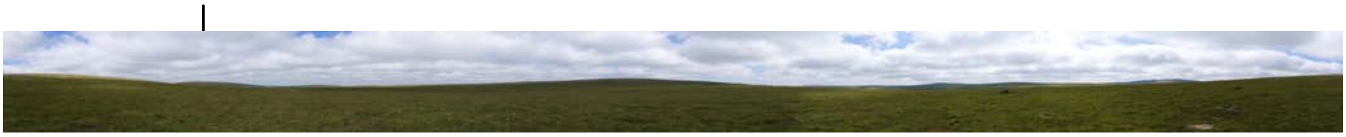
Northern Stone Circle

P1

P2

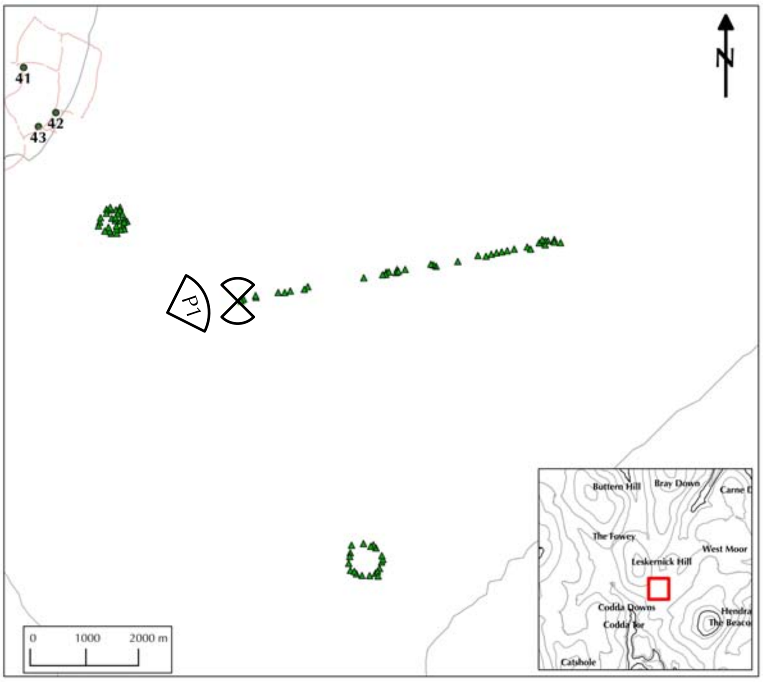


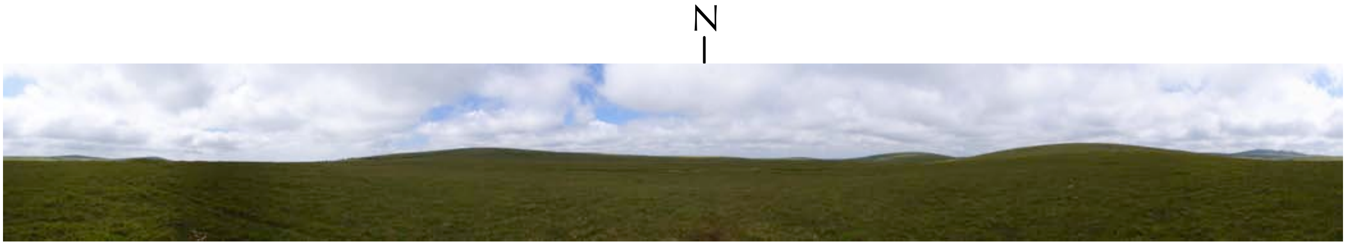
N



Stone Row

P1

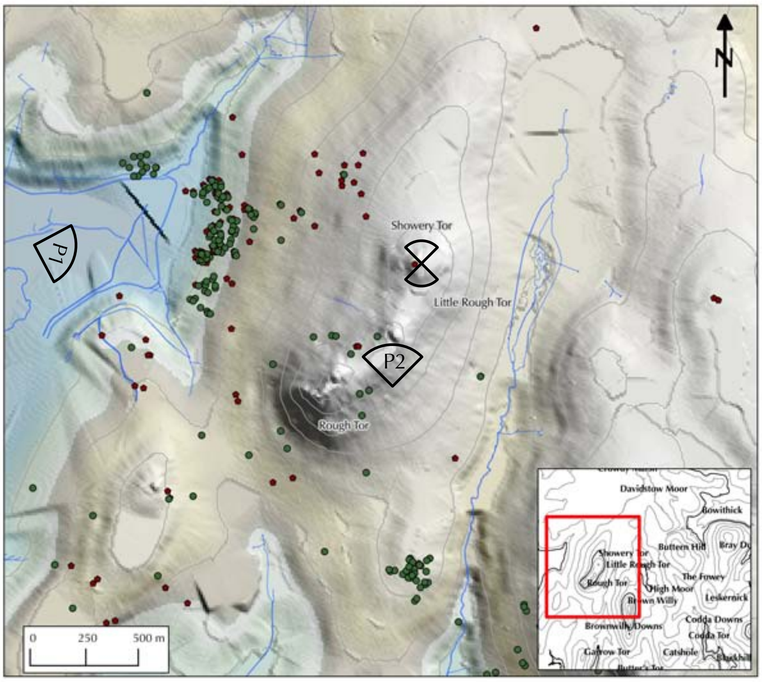


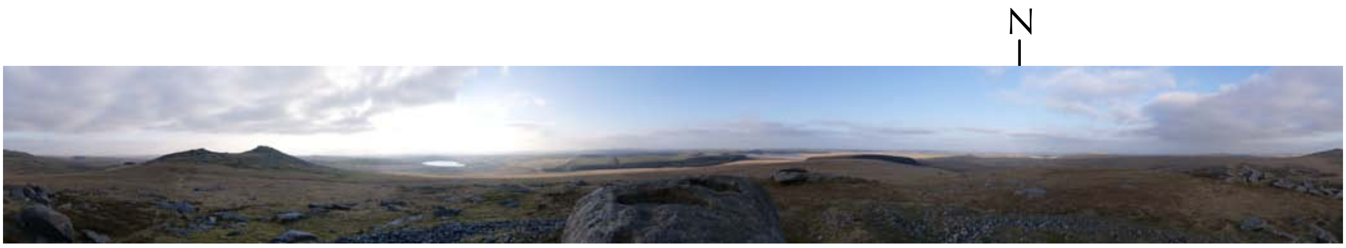


Roughtor

P1

P2





Appendix 3 – Software

Software	**Version Used**	**URL**	**Purpose**
Quantum GIS	1.8.0	http://qgis.org/en/site/	Geographic Information System
GDAL/OGR	1.9.1	http://www.gdal.org	Geoprocessing
GRASS GIS	6.4.1	http://grass.osgeo.org	Geographic Information System
Unity3D	3.5.6	http://unity3d.com/	Game-Engine
Vuforia	2.6.8	http://www.vuforia.com/	Marker-Based Augmented Reality Engine
OpenOffice	3.4.1	http://www.openoffice.org	Word-Processing and Spreadsheet
Sketchup	7.1.6859	http://www.sketchup.com	3D Modelling
blender	2.63	http://www.blender.org/	3D Modelling
Meshlab	1.3.0	http://meshlab.sourceforge.net	3D Modelling
R64	2.15.1	http://cran.r-project.org/bin/macosx/	Statistics
ARK	1.1	http://ark.lparchaeology.com	Database
Processing	2.0b7	http://processing.org/	Arduino Control
Textmate	1.5.11	Http://macromates.com	Text-Editing/Coding
GIMP	2.1.6	http://www.gimp.org/	Photo-manipulation
Panini	0.71.101	http://sourceforge.net/projects/pvqt/	Panorama Viewing Software
Hugin	2011.5.0.5833	hugin.sourceforge.net/	Panorama Creation Software